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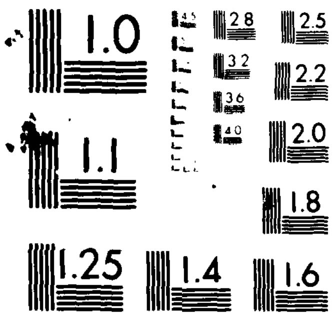

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EXPOSURE

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Text For The SAIL Standard

This issue of *Exposure* is composed of the complete text of the Serial ASCII Instrumentation Loop (SAIL) data communications standard as drafted by technical members of the marine research community. Research vessels operating in the federal and university research communities are not outfitted with a common digital methodology to access or exchange operational data. To a large extent, science leadership is based on the widespread availability of instrumentation. In an earlier era, marine scientists could make fundamental discoveries with the equivalent of sealing wax and string. Today, an occasional worthwhile observation is made with simple tools, but the more significant advances now depend on the application of complex instrumentation. In most instances, new instrumentation techniques make possible a tenfold or greater speed in data collections,and in other instances make possible the measurements for experiments before inaccessible. Although this standard has other instrumentation applications, it is presented as one candidate specifically for intravessel digital data communications from sensors that monitor vessel parameters (position, speed, heading, etc.). The marine research community is very diffuse geographically and in research interests, which has partially contributed to the slow development of standard design criteria. However, standardization contributes to efficiency and technology dissemination because standards form the root words of a language for technical information transfer.

The SAIL standard merges the bit serial communications standard in the current-loop mode, with its inherent noise immunity, and the ASCII standard which defines the character format and provides a reasonable linkage to high-level computer languages. Also, the instrumentation system incorporating this standard is partitioned where the loop controller and each data station (sensor) can be physically remote from each other. *(Continued on page 8)*

September 1981

Serial ASCII Instrumentation Loop (SAIL) Data Communications Standard - August 1981

1. OVERVIEW

The SAIL (Serial ASCII Instrumentation Loop) data communications standard defines the hardware and software components of a digital message interface between shipboard data sources and shipboard data users of all kinds. It is principally intended for use in the construction of data acquisition and distribution systems, although other applications are in no way ruled out by this emphasis. A typical SAIL installation consists of three components: the interface modules, the SAIL loop, and the system controller.

The interface modules, or data stations, are of two types. Sensor interface modules convert data from a sensor or other data source into the standard format of the SAIL protocol. Data distribution modules convert data messages from the SAIL format into the format required by a user's display or recording device.

The SAIL loop provides a standardized communication channel for message interchange, along with a polled address control protocol for regulating the flow of data through this channel.

The controller of the system utilizes the facilities of the loop protocol to sequence and control the acquisition of data from the sensor interface modules, and its subsequent delivery to the data distribution modules. A typical system would have one controller and up to 80 data modules.

The purpose of this standard is to ensure the interchangeability of these components among various SAIL based sysems. The standard provides a detailed definition of the loop control protocol (section 2), the electrical characteristics of the loop (section 3), and the electrical and logical requirements for a device which is to be connected to the loop (section 4). Beyond the standard interface definition, the nature and functions of the data modules and in particular the system controller are deliberately not specified, in order to allow users maximum flexibility in utilizing the capabilities of the SAIL approach.

2. LOOP PROTOCOL

2.1.0 Signalling. All equipment in a SAIL installation shall be connected together in series by a half duplex 20 milliampere (mA) current loop. A mark or logical one condition shall be defined as the flow of 20 mA +-5 mA through the loop. A space or logical zero condition shall be defined as the flow of 0 mA +5,-0 mA through the loop. Loop currents of 5 mA to 15 mA shall have no defined meaning.

2.2.0 Frame Format. All communications within the SAIL system shall utilize the ASCII 7-bit subset, including control characters, for asynchronous communication. Each character frame shall consist of:

2.2.0 Continued

Start Bit
Data Bits 1 through 7; bit 1 is LSB
Parity Bit
Stop Bit
Second Stop Bit; required only at 110 baud.

The use of binary or other non-ASCII data formats is specifically prohibited.

2.2.1 Parity Bit. The use of parity generation and detection is not required by this standard, but is recommended wherever feasible as a reliable and effective method of ensuring communication channel integrity.

A) The parity bit shall always be present within any transmitted character frame, whether or not parity checking is implemented.

B) Transmit and receive parity checking, where implemented and when enabled, shall be switch *selectable for either odd* or even parity.

C) If parity checking is not implemented or not enabled the parity bit may be either a mark or a space, on a frame by frame basis.

D) All system equipment including controllers and interface modules shall have the capability to disregard received parity, in order to assure compatability with equipment which does not support parity checking.

2.2.2 Half Duplex Operation

A) Half Duplex as used in this standard specifies that one communication channel shall be employed for two way communication, with information flow in one direction at a time only. Thus at any given instant only one device on the loop shall be empowered to transmit by making (mark) and breaking (space) current loop continuity. All other devices on the loop at that time shall passively maintain loop continuity while detecting the presence (mark) or absence (space) of the 20 ma loop current.

B) In section 2.12 below, this definition is extended (with exceptions as noted) to include the requirement that each transmitting device be capable of simultaneously receiving its own transmission, by detecting the presence or absence of the 20 mA current on the loop. This allows a check on the integrity of the transmitted data.

2.3.0 Unaddressed State. Unless otherwise specified in this standard, or directed by commands of the system controller, all equipment in the system shall be in the Unaddressed state. Equipment in this state shall not transmit under any circumstances and shall continuously monitor the loop for further addressing, as described in sections 2.5 and 2.6 below.

2.4.0 Attention Character. *One character, ASCII "#" (hex 23), is* reserved as an attention (ATTN) command to all elements in the system. Only "#" shall be used for ATTN and all uses of "#" shall be interpreted as ATTN.

2.5.0 System Address. A system address shall consist of ATTN followed by a character string. Numeric addresses shall be of two digits only and are reserved as follows:

#00	System Baud Rate Select -- see 2.10.0
#01 to #19	UNOLS Uniform Ship Parameters - see Appendix 1
#20 to #78	unreserved
#79	Synoptic Set command -- see 2.11.0
#80	Synoptic Clear command -- see 2.11.0

2.5.1 Special Address. A special address may be assigned by specifying an alpha character *as the first of* the address string. Thus, #A27 and #M753 are valid special addresses. This paragraph specifically excludes special addresses which begin with numeric or other non-alphabetical characters.

2.6.0 Open State

A) Upon receipt of its own address a module shall enter the Addressed or Open state. The module is empowered to transmit to the loop only when in this state, and at no other times.

B) Exit from the Open state shall occur upon the next occurrence of ATTN (#), upon detection of a loop communication error (see 4.3), or upon occurrence of a loop Break condition (see 2.9.0).

C) The action of a module when in the Open state is not specified by this standard, but may involve transmission or reception of a data message, or performance of a programmed function. For verification purposes, it is recommended that entry into the Open state be signalled by the return of a message by the addressed module.

D) Modules which respond to the Open state with data returns, command prompts, or other messages shall begin transmission immediately after decoding their address. The allowable delay between address decode and beginning of

2.6.0 Continued

transmission is not specified, but should be kept as short as possible in order to maximize loop throughput.

2.6.1 Open Functions. Multiple command/response sequences are permitted while a module is in the Open state, provided that such communication is in conformity with all sections of this standard.

2.7.0 Terminating Character

A) One character, ASCII "ETX" (hex 03, End of Text), is reserved as a message termination character. Each transmission on the loop from an addressed device shall end with the ETX character, regardless of message length. No other character shall be used as the message terminator and all uses of ETX shall be interpreted as signifying message termination.

B) The following character strings are not transmitted by an addressed device and hence shall not contain ETX in any context:

1. *address strings, per section 2.5 or 2.8*
2. baud rate commands, per section 2.10.1
3. synoptic data access commands, per section 2.11.

2.8.0 Information Message. Each module residing at a numeric address shall respond to an additional address formed by adding 08 hex to the ASCII character code for the first digit of its address. The module shall respond to this address with a message identifying the module and providing information about the module and its associated sensor or data output device (capabilities, location of calibration data, etc). If the module address is "#NM" where N and M are numerals, then the address for the message described would be "#" "$N+8_h$" "M". The corresponding characters from the ASCII set are as follows:

Original Address Character	Message Address Character
(N)	($N+8_h$)
0	8
1	9
2	:
3	;
4	
5	=
6	
7	?

Thus, module number 38 would be addressed by "#;8" to get the associated information message.

2.9.0 BREAK. The BREAK (or BRK) condition is defined as any loop open condition (continuous space) which lasts for more than 150 milliseconds.

2.9.1 Initialize State. Upon detection of the BREAK condition, all equipment on the loop including modules and controllers shall go to a known state. This state called Initialize (INIT) shall include the following:

A) loop coupler to mark or closed condition (unless equipment is deliberately generating the break)

B) standard baud rate selected -- see 2.10.0

C) synoptic clear condition -- see 2.11.0

D) further requirements for interface modules as discussed in 4.2.0.

Upon termination of the BREAK condition all equipment shall move from INIT to the Unaddressed state (see 2.3), ready to address or be addressed.

2.10.0 Standard Baud Rates

A) Each SAIL interface module shall be capable of operation at both 110 and 300 baud, with the desired rate chosen by a switch located on the module. The rate which is chosen becomes the Standard Rate for that module, and shall be selected by that module upon entry into the INIT state. Every module in a system should be set for the same standard rate, which then becomes the system standard rate.

B) At any given time the baud rate which is in use by the system is referred to as the Effective Rate. Upon INITialization the *effective rate equals the standard rate.*

2.10.1 Optional Baud Rates

A) SAIL modules may optionally have the capability to operate at rates greater than 300 baud. Such higher rates shall be programmable over the loop at any time, by addressing the system at the effective rate on address #00. The new baud rate shall then be sent as a string of 5 characters DDDDD which give the desired baud rate in Hertz.

B) Any module capable of operation at the requested rate shall switch immediately to that rate, which becomes the new effective rate.

2.10.1 Continued

C) Any module incapable of operation at the requested rate shall enter the Idle state. In this state, all loop activity except for BREAK shall be ignored by the module; reception of BREAK shall cause the module to inter the INIT state.

As an example, upon INITialization by BREAK all modules are at the standard rate. #00_2400 is sent out and all modules with the capability to run at 2400 baud switch to that rate; further addressing must then be done at 2400 baud.

2.11.0 Synoptic Data Access. The synoptic data access function allows data to be acquired from several sensor interface modules without the time skew which normally occurs when each module is polled sequentially.

A) Reception of the Synoptic Set address (#79) shall cause each sensor interface module to cease further data acquisition and store data internally for later transmission when the module is addressed. At the option of the module designer, Synoptic Set may cause a module to acquire and then hold a data value, or it may simply cause the module to cease further updating of the data value which is to be transmitted when the module is next addressed.

B) The Synoptic Set condition shall apply to each data value within any module which is designed to handle more than one data value.

C) Release from the Synoptic Set condition shall occur for each data value individually after the stored data is returned by the module (while in the Open state), or for all data values simultaneously upon reception of the Synoptic Clear address (#80).

D) All equipment in the system shall go to the Synoptic Clear condition upon entry to the INITialize state.

2.12.0 System Error Recovery. All SAIL compatible devices shall be designed to check the integrity of data which they transmit over the loop, as described in the paragraphs below, unless strong technical considerations militate against the inclusion of this capability in the device. Devices which for any reason do not include such error checking capability shall be considered SAIL compatible, but must contain in their documentation an explicit statement to the effect that they do not support system error recovery per section 2.12 of the SAIL standard.

A) During any transmission on the loop, the transmitting device shall simultaneously monitor its own transmission, using its receive loop coupler. Error checking shall be performed on the bit stream so received, using either or both of the following methods:

2.12.0 Continued

1) Bit-by-bit or character-by-character comparison of transmitted and received bit streams.

2) Identification of framing errors (misplaced stop bit) or parity errors in the received bit stream.

B) Detection of any transmit error shall cause transmission to cease at the end of the character frame for which the error was detected, and the device transmit loop coupler to be closed.

C) Any data module which detects a transmit error shall further immediately enter the Unaddressed state.

D) The response of a controller upon detecting a transmit error is not specified at this time, pending the development of a collision detection multi-controller access protocol. A reasonable wait followed by a retransmit attempt is recommended. It is further recommended that all controllers be designed to check for loop activity before beginning any transmission.

2.13.0 State Diagram. Figure 1 is the state diagram for a SAIL interface *module and is in conformance with all parts of this standard.*

3. LOOP HARDWARE

3.1.0 Loop Architecture. At each access port on the ship the SAIL loop shall appear to be one continuous loop.

3.2.0 Electrical Characteristics. The ship shall supply 20 ma DC to the loop with a supply such that the open loop voltage does not exceed 100 V DC. *The 100 V limit may* preclude direct connection of some terminals and computer interfaces.

3.3.0 Ground Isolation. Isolation of the loop from ship's ground shall allow loop operation with voltages of 500 V DC or AC from the loop to ground. (This specification also applies to module couplers; see 4.4.) The loop shall not be grounded at any point.

4. INTERFACE MODULE REQUIREMENTS

4.1.0 Fail Safe. Local failures such as power loss or hardware malfunction shall cause the module affected to close its transmit loop coupler.

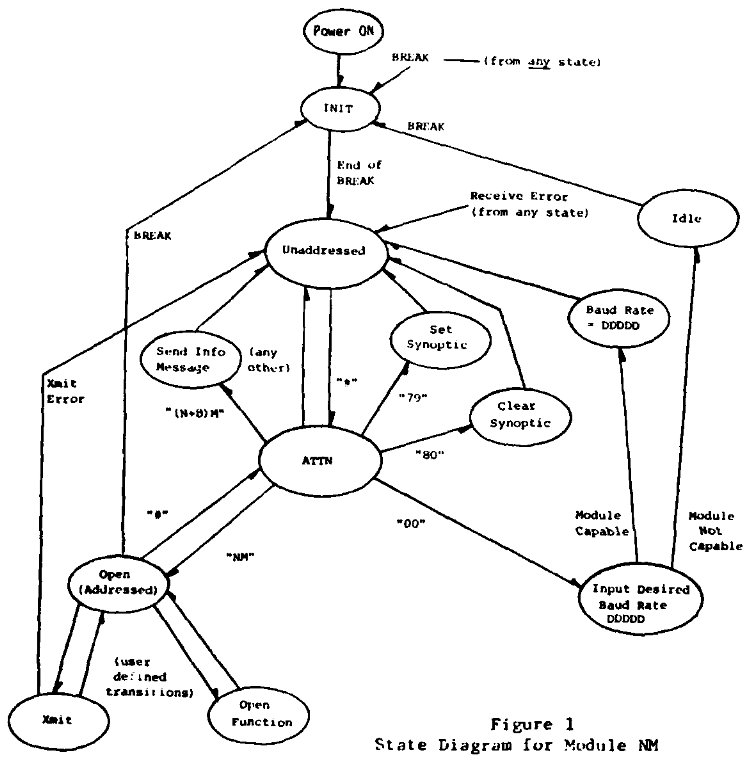


Figure 1
State Diagram for Module NM

4.2.0 Module INITialize. All interface modules shall enter the INITialize state during power up or loop BREAK conditions. Module entry into INIT shall cause the following actions, in addition to those discussed in 2.9.1:

E) sensor or data source handshake, if any, released
F) other actions as may be appropriate to the application.

Modules are not required to clear internal data buffers during INIT, but must release control of external data devices to the greatest extent possible in order to avoid locking up the device for external users. Upon termination of the INIT state all modules shall perform any required data source initialization procedures and then enter the Unaddressed state.

4.2.1 Break Detect. It is recommended that the interface module BREAK detect function be implemented in hardware rather than software, to provide unconditional initialization upon BREAK.

4.3.0 Module Error Recovery. Modules which are enabled to perform parity and/or frame error checking on bit streams received from other devices on the loop shall enter the Unaddressed state immediately upon detection of such a receive error, if they are not in that state already.

4.4.0 Module Ground Isolation. The transmit and receive couplers for each module shall leave the loop isolated from ground for potentials of 500 V DC or AC. See also section 3.3.0, and Appendix 2.

Appendix 1
UNOLS Standard Ship Parameters

The following list of observable parameters has been extracted from the UNOLS Preliminary Report (Feb. 26-28, 1979) entitled "Basic Minimum Scientific Support Capabilities for UNOLS Vessels: Supply, Operation, and Maintenance", pg. 44. This list, called the UNOLS Standard Ship Parameters List, represents a basic capability level for a general purpose SAIL installation. The addresses shown have been allocated on a preliminary basis.

Address	Parameter	Data Format	Notes
#01	Date -- day, month, year	#01_DD_MM_YY	Note 1
#02	Time -- hour, minute, second	#02_HHMM_SS	Note 2
#03	Position -- SatNav DR	#03_lat_long_fix message	Note 3
#04	Position -- LORAN C	#03_lat_long	Note 4
#05	Position -- future use		
#06	Ship Speed Over Water	#06_KKK (Kts. x 10)	
#07	Ship Gyrocompass Heading	#07_DDD (integer degrees)	
#08	Water Depth -- from sounder	#08_MMMM (integer meters)	
#09	future use		
#10	Wind Speed Relative to Ship	#10_KKK (Kts. x 10)	
#11	Wind Direction Relative to Ship	#11_DDD (integer degrees)	
#12	Sea Surface Temperature	#12_DDDD (degrees C x 100)	
#13	future use		
#14	future use		
#15	Air Temp/Wet Bulb Temp	#15_DDDD/DDDD (degrees C x 100)	
#16	Barometric Pressure	#16_MMMM (millibars x 10)	
#17	Winch #1 wire out/speed/tension		
#18	Winch #2	#18 MMMM/MMM/PPPPP	
#19	Winch #3	(meters out/meters per min/pounds)	

Appendix 1 Continued

Notes

1. Julian Day Option

2. Time format is in 24 hour clock form for hours and minutes, followed by "space" seconds. For synchronization purposes, the time data may optionally be followed by a "mark" (loop closed) of up to two seconds, and then the ASCII "@" symbol. The leading edge of the "@" start bit shall be timed to occur on the second previously transmitted, +- 1 millisecond.

3. Open functions can be used for fix messages, etc.

4. Open functions for time and signal quality messages. May be switched to primary information.

Appendix 2
Example Isolated Loop Coupler

To satisfy all of the requirements of sections 3 and 4 of this standard, isolation couplers are required. To aid designers, a coupler which meets these requirements is illustrated in Figure 2. The coupler provides 500 V minimum isolation (1500 V typical) between instrument and loop, will withstand loop voltages in excess of 100 V in the "open" condition, and has a typical voltage drop of 4.5 V in the "closed" condition. The coupler is not sensitive to loop polarity and may be connected to the loop in either direction.

In the absence of LED excitation to the upper optocoupler, the loop is closed. Base drive for the high voltage transistor (2N5551) is supplied by a current regulator diode (1N5295) at .82 mA. Maximum collector - emitter voltage seen by the optocoupler transistor is less than 3 V. When excited by LED current from the module, the optocoupler shunts the base current around the HV transistor, opening the loop. On the receive side, the LED in the lower optocoupler simply uses loop current for exitation of the receive phototransistor. The 500 ohm pot reduces phototransistor saturation by shunting some current around the LED, and can be adjusted to set the switching point of the receiving circuit to the center of the 5 to 15 mA "forbidden band" (see 2.1.0).

The transmit LED and the receive phototransistor can be connected as appropriate to the system involved. In Figure 2 they are set up for direct interface to 5 V logic signals, with a logic high level corresponding to loop closed (mark) and a logic low level corresponding to loop open (space). Other arrangements, for RS-232 interface, etc. can be easily implemented.

This circuit is provided merely as an example and should not stop designers from providing alternative solutions which meet the interface requirements of the standard. Most component values in the circuit are not critical, although attention should be paid to optocoupler rise and fall times when operation above 2400 baud is desired.

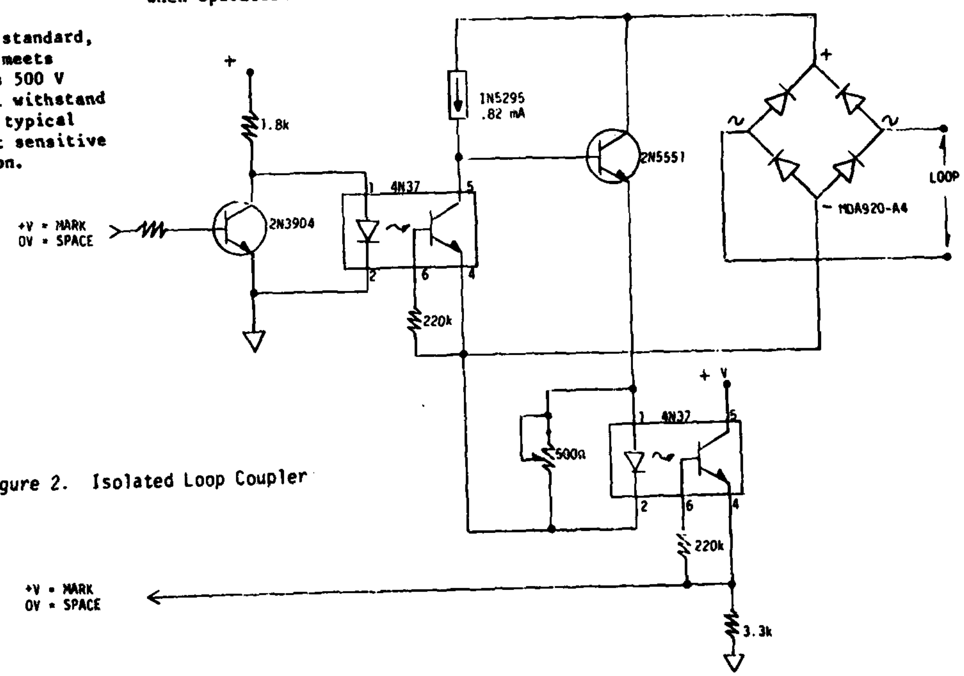
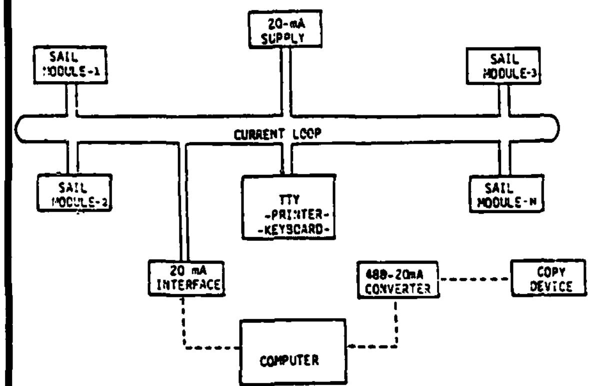


Figure 2. Isolated Loop Coupler

The electronic hardware modules necessary to accomplish the rudimentary goals of shipboard parameter monitoring, and which incorporate the SAIL standard, are illustrated in the following diagram.



The SAIL system hardware components are:

- A 20-mA loop and current power supply distributed about the ship. (A 58-V current source is adequate for ten SAIL modules on a loop.)
- A 20-mA loop coupler (interface) that is used to provide an 8-bit parallel output port from the loop controller to the serial data loop.
- SAIL modules which are designed to provide 20-mA loop serial ASCII communications over a span of baud rates, address recognition, unique messages, and the preparation of a digitally encoded signal from the sensor.

A standard reflects the quality of attention given to it by the users. Sharing comments on improvements and applications of SAIL are essential to its maintenance.

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