SDI-12 SUPPORT GROUP
SERIAL DATA INTERFACE AT 1200 BAUD

NEWSLETTER

SPRING 1997

Updated Copy of the SDI-12 Specification

An updated copy of the SDI-12 Specification is included with this newsletter. The version number remains unchanged at Version 1.2. The difference between this version, dated October 21, 1996 and the April 12, 1996 version, are clarifications only. No technical changes were made to the specification. The clarifications are:

1) Page 2. Added the following statement, which was in Version 1.0, but omitted from Versions 1.1 and 1.2 (4/12/96) by mistake.

> *"In the following specifications, all values not indicating specific limits, have an allowable tolerance of ±10% of the value."*

2) Page 12. Added text to clarify when ttt seconds begins and added text to advise sensor designers to return a ttt value that is greater than the time it takes the sensor to take a measurement.

> *"The ttt time period begins upon completion of the transmission of the line feed character."*

> *"A sensor should return a ttt value greater than the time it takes to make a measurement, to allow for timing tolerances and for the service request. (See section 4.4.6.)"*

3) Page 14. Added text to clarify when ttt seconds begins.

> *"The ttt time period begins immediately after the sensor transmits the <LF> character."*

The technical committee felt that the above changes should be added to the SDI-12 Specification, without changing the version number. Although the new copy of the specification is dated October, 1997, it has not been officially released until now. A copy of it has been posted on our web page.

SDI-12 Verifier Software Upgrade

NR Systems, Inc. has released Version 2.0 of the SDI-12 Verifier software, which is used to test Version 1.2 of SDI-12. This SDI-12 Verifier now has the ability to test sensors for the correct use of the Concurrent Measurement Commands (C commands), the Continuous Measurement Commands (R Commands), the Change Address Command, and the Address Query Command. Version 2.0 of the SDI-12 Verifier software has a variety of tools to test SDI-12 products for the correct use of these commands.

Like previous versions of the SDI-12 Verifier software, Version 2.0 is an MS-DOS based program. Version 2.0 runs on 286, 386, 486, and Pentium processors.

Call NR Systems, Inc. (801-752-4200) for more information about the SDI-12 Verifier

The SDI-12 Support Group Is On-Line

The SDI-12 Support Group now has a web page. Please visit this web page at http://www.amassdata.com/sdi12-home.htm. The site will soon be accessible via its own URL. The web page was designed by Marcel Leclerc, of Amass Data Technologies, Inc. Marcel works with Bill Thomas, who is the secretary of the SDI-12 Support Group. If you have any suggestions about improving the web page, you can reach Marcel via e-mail at amassinf@amassdata.com. Many thanks to Marcel for bringing us into the modern age by creating the web site.

We will keep the web page up to date with all news about the SDI-12 Support Group, announcements of all meetings, minutes from all SDI-12 Support Group meetings, the most recent version of the SDI-12 Specification, and other pertinent information.

We plan to add links to all companies that are members of the SDI-12 Support Group. If you would like us to add a link to your web page, please send us your web page address. Your company must be a member of the SDI-12 Support Group to have a link from the web page.

The SDI-12 Support Group is organized exclusively for educational and scientific purposes. The educational purpose is to inform all interested parties about the SDI-12 interface by providing all interested parties with copies of the SDI-12 Specification and providing other information, as appropriate, about the SDI-12 Specification. The scientific purpose is to publish the SDI-12 Specification and to upgrade the Specification when technical changes are necessary to facilitate the collection of environmental data using the SDI-12 Specification.

SDI-12 Support Group Corporate News

Tax Exempt Status

The SDI-12 Support Group has received tax exempt status from the Internal Revenue Service (IRS). The Support Group is exempt from Federal income tax under section 501 (a) of the Internal Revenue Code. Under section 501 (a), however, membership dues cannot be claimed as tax deductions. Under section 6113 of the Internal Revenue Code we must include an explicit statement (in a conspicuous and easily recognizable format) that contributions or gifts to the Group are not deductible as charitable contributions for Federal income tax purposes. The IRS ruling on the Group determined that although the Group is exempt from income tax, membership dues are not deductible because the Group is not a charitable organization, or acting solely in the public interest.

Corporate Status

This SDI-12 Support Group operates as a non-profit corporation in the state of Utah. The board of directors for the corporation are:

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Our Next Meeting

The next meeting of the SDI-12 Support Group will be this fall, in Long Beach California, at the American Water Resources Association Conference. The conference is scheduled for October 19-23. All members of the SDI-12 Support Group will receive an invitation and an agenda for the SDI-12 meetings at least 30 days in advance.

Increasing the Size of the Technical Committee

Under the Bylaws of the SDI-12 Support Group, the size of the Technical Committee is limited to nine people. The Group has been asked to increase the size of the Technical Committee, to allow room for more users of SDI-12 equipment. A representative from Environment Canada would like to join the committee. Because Environment Canada is a large consumer of SDI-12 products, their viewpoints about SDI-12 would be most welcome. This was met with a favorable response at the meetings of the SDI-12 Support Group last fall. We cannot increase the size of the technical committee without approval of a two-thirds majority of the SDI-12 Support Group's membership. Therefore, the Technical Committee is asking for a vote to increase the size of the Committee from nine to twelve members. Please take the time to return the attached ballot with your dues.

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Continued Interest in SDI-12

Since last September, Mike Jablonski has received 16 requests for the SDI-12 Specification. All of these requests were from companies that said they are considering adding SDI-12 products to their product lines.

SDI-12 Support Group Corporate News

Wireless SDI-12

The Technical Committee held a long discussion last fall about the possibilities of upgrading SDI-12 to use a packetized, radio compatible, communications scheme. All members of the technical committee felt that this had merit, but it would require a significant change to SDI-12. The committee felt that it could not pursue it further without feedback from the membership. We would, therefore, like to here from you about this. Please comment on the following:

- the need for a wireless SDI-12;
- getting faster data rates;
- communication over wires at longer distances.

Please return your comments about this on the attached form. If you have any ideas on how to implement a wireless SDI-12, please write a brief description of it and submit it to the Technical Committee

SDI-12 Logo

The South Florida Water Management District, which uses lots of SDI-12 products, said that they would like some type of certification that an SDI-12 product does, in fact, comply with the SDI-12 Specification. Under the bylaws of the SDI-12 Support Group, however, certification programs for compliance testing cannot be provided by Group. The Group cannot endorse or certify SDI-12 products. The South Florida Water Management District has suggested that manufacturers of SDI-12 products add a logo/sticker to SDI-12 products as a statement that the product has an SDI-12 interface and that it does, in fact, comply with the SDI-12 Specification. In other words, each company would certify that their device complies with SDI-12 by the placement of the logo onto their product. The logo/sticker would be designed and provided by the SDI-12 Support Group, but the Group will not certify or endorse any products. Please let us know your feelings about this by returning the attached feedback sheet.

Join the SDI-12 Support Group

If you are not a member of the SDI-12 Support Group, please join us. Membership dues are $120.00 per year. As a member you will receive our newsletter which is published twice a year and notice about our yearly meetings. As a member you will also have a voice and a vote on all proposed changes to the SDI-12 Specification. To join, simply return the attached membership form with your dues.

Member Articles

SDI-12 Data Line "Off" Impedance Design Considerations

Submitted by *Rick Lockyer (Handar)*

For proper operation, the SDI-12 data bus must present a logic low to all nodes it connects to when the bus is idle. Since the bus is not actively driven during idle conditions, there must be some impedance to ground somewhere to insure the data line voltage remains near ground. The system must also be designed to insure that valid signal levels will be present on all receiving circuits, even in the presence of noise.

The typical implementation of the SDI-12 data bus circuit is a 74HC125 tri-state bus driver for driving the data bus, in parallel with an another CMOS device input for receiving data. Designers must be sure to always provide a determinate logic state voltage to all CMOS device inputs to prevent the device from drawing excessive supply current should its input be allowed to wander to a voltage between valid logic low and logic high. In order to allow manufacturers to test sensors and data loggers without needing data bus termination to be externally provided, the decision was made to require each and every device to provide its own impedance to ground.

The impedance to ground is provided by a resistor. The value of this resistor is not arbitrary, nor must it be a singular value. A range of values would be equally sufficient, with the range being determined by tradeoffs on the impact of several realities of the input / output circuitry and data network in total.

The tri-state driver leakage current and CMOS input leakage current combine to form a current source through the resistance value to ground. Any voltage dropped across the grounding resistor will be seen on the data bus as an elevated voltage above ground during idle conditions, cutting into the noise immunity for detection of the proper logic state on the bus. This phenomenon is best resolved by making the grounding resistance value as small as possible.

The data signal is a square wave which may be considered to be the superposition of harmonic frequency components. Since the data bus acts as a radiating antenna, the energy of the higher frequency components of the square wave must be diminished to prevent radiation in excess of FCC Part 15 requirements. These higher frequency components also add to the phenomenon called "ringing" which is successive overshooting and undershooting of the data signal wave form when the square wave goes through a level transition. Data errors can result if ringing is not controlled. Both of these features can be remedied by the addition of a filter on the data line which attenuates the higher frequency components of the square wave. The filter is realized with a resistance in series with the tri-state driver output followed by a capacitor to ground. The filter resistor and the data bus grounding resistor form a voltage divider between the data output driver and the data bus, decreasing the logic high driven voltage which cuts into the noise immunity. In opposition to the requirements imposed above by the leakage current, the voltage divider effect is minimized by making the grounding resistor value as large as possible.

So, considering these two conflicting requirements we hopefully have a situation where one sets the minimum value and the other sets the maximum value with sufficient overlap to pick realistic values for the resistive components of the SDI-12 bus interface circuitry. First, look at the two terminal equivalent circuit for the device driving the bus to a logic high value. It may be considered to be a voltage source in series with a resistive value. The voltage source value is the open circuit voltage seen looking into the SDI-12 bus interface, call it V. The resistive element may be found by taking V divided by the short circuit current at the bus interface. To determine these values, assumptions must be made as to the driving device actual 5 volt supply value as well as assuming standard CMOS HC high current device output characteristics. I will assume the 5 volt supply is regulated to within 2.5% over temperature, and that the output impedance of the CMOS driver is 100 ohms. While the SDI-12 specification allows a total source impedance of 2000 ohms, the values used should reflect the actual chosen values. Looking at the recommended circuit, the CMOS driver passes through a resistor, call it Rt, before seeing the grounding resistor, which we will call Rg. The T circuit is completed with another resistor between the SDI-12 bus and the grounding resistor, which is the same value as Rt recommended as being 510 ohms. Assuming the 5 volt supply is actually

$5v - 2.5\% = 4.875v$

and the CMOS output voltage lightly loaded gets within .1 volts of this value, the open circuit voltage will be

$Vo = 4.775 * Rg / (Rg + Rt + 100)$

Assuming Rt is 510 ohms + 5%, this becomes

$Vo = 4.775 * Rg / (Rg + 636)$.

Leakage currents are taken to be 0 since they would only help this scenario. The 100 in the equation is the CMOS device output impedance. The short circuit current is

$Is = 4.775 / (Rt + 100 + Rt \,||\, Rg)$
$= 4.775 * (Rg + 536) / (1172 * (Rg + 291))$.

The equivalent series resistance is then

$Ro = Vo / Is$
$= Rg * 1172 * (Rg + 291) / ((Rg + 636)*(Rg + 536))$.

If it is assumed that Rg >> 636, Ro may be approximated with Ro = 1172, valid in worst case analysis since the actual value will be smaller, and smaller helps this scenario. The long and short of this exercise is that the driving node looks like a voltage source of value Vo driven through a 1172 ohm resistance.

Assume that all nodes have the same values for Rg and Rt. The SDI-12 specification allows a minimum high voltage of 3.5v. This is not adequate for standard CMOS input circuitry. The input components Rt and Rg form a voltage divider to the voltage applied at the SDI-12 bus to the CMOS input. Examination of the CMOS input requirements for worst case assumed supply voltage of 5v + 2.5% yields a minimum input high of approximately 3.59v. Adding .25v for noise margin, the minimum input voltage at the SDI-12 bus for a high is

$Vh = (3.59 + .25) * (Rg + Rt) / Rg$.

The load on the SDI-12 bus due to the Rt Rg series combinations of each receiving device is

$(Rg + Rt) / N$

where N is the number of receiving devices. Remembering the equivalent circuit for the driving node, the voltage on the loaded SDI-12 bus when a logic high is driven is:

$Vbh = Vo * (Rg + Rt) / (N * Ro + Rg + Rt)$
$= Vo * (Rg + 536) / (Rg + N * 1172 + 536)$

For proper operation Vh < Vbh, or:

$3.84 * (Rg + 536) / Rg < 4.775 * Rg * (Rg + 536) / ((Rg + 636) * (Rg + N * 1172 + 536))$

or:

$.935 * Rg \wedge 2 - 4500.48 * (N + 1) * Rg - 2442.24 * (1172 * N + 536) > 0$

When N = 10, the minimum requirement of the SDI-12 specification, solving for Rg yields:

$Rg > 53545$ ohms.

Solving for Rg when N is a more desirable 32 :

$Rg > 159464$ ohms.

From the equation for Vh above, the minimum loaded logic high voltage produced by a device should be:

$3.84 * (Rg + Rt) / Rg$

or

$Vh = 3.85v$

and NOT 3.5v as stated in the SDI-12 specification.

To specify the upper limit on Rg, we must examine the scenario when all bus drivers are off. The voltage seen at any SDI-12 bus CMOS input circuit must not be greater than the maximum voltage for a logic low minus an acceptable noise threshold. We can not assume that the devices are in a low power state so the maximum ground offset voltage allowed by the specification, .5v, must be included in the analysis. Remembering the equivalent voltage and source impedance circuit for the SDI-12 bus interface, it should be clear that the voltage seen on the bus will never be higher than the open circuit voltage of any single device. The analysis is thus reduced to the effects of the leakage current on the resistive components in a single device interface circuit as seen from the SDI-12 bus, in short, the open circuit voltage. The open circuit voltage is effectively applied to external CMOS devices through a voltage divider equivalent to 2*Rt with Rg. It is 2*Rt because the local Rt between the local Rg and the SDI-12 bus is in series with the same for the external device. At low supply voltage on the external device, the minimum low input voltage is approximately .975v. From this value, we must subtract the maximum ground differential of .5v and the desired noise threshold of .25v, leaving a maximum effective bus open circuit voltage during idle conditions of:

$Vl = (.975 - .5 - .25) * (Rg + 2 * Rt) / Rg$
$= .225 * (Rg + 2 * Rt) / Rg$

The open circuit voltage produced by leakage current Il is simply

$Voi = Il * Rg$.

For proper operation, Voi < Vl,

or:

$Il * Rg < .225 * (Rg + 2 * Rt) / Rg$

or:

$Il * Rg \wedge 2 - .225 * Rg - 218.025 < 0$
taking Rt = 510 - 5%

The leakage current produced by CMOS circuitry varies strongly with temperature, with worst case occurring at high temperature. Specifications for leakage current are typically given at 25C and 85C. For a CMOS input, the maximum leakage currents are 0.1 uA and 1 uA respectively for 25C and 85C. For tri-state outputs the maximum leakage currents are 0.5 uA and 5 uA respectively. Using these values, the upper limit for the grounding resistance for 85C operation would be:

Rg < 38445 ohms, which is in conflict with the above stated minimum Rg.

The specifications stated by chip manufacturers as not 100% tested, which is the case here, are usually very conservative so that the manufacturer can state a maximum without incurring the cost of 100% screening. Bearing this in mind, experienced designers know that the 25C maximum specifications are safe limits for design choices when the operating temperature range upper end is closer to 25C than 85C. Taking the 25C maximums as design limits, the upper end for the grounding resistance value becomes:

Rg < 375966 ohms.

The range of acceptable values for grounding resistance to the nearest 5% standard value for a standard outdoor environmental operating temperature range and support for up to 32 sensors is therefore:

160k ohms =< R =< 360k ohms

The requirements of the SDI-12 data bus specification may be verified without internal circuit analysis with four tests. The "on" state source impedance may be tested by measuring the space level voltage on the data bus while driving an external 5k ohm resistor between the data bus and ground. The resistor simulates a worst case load. The space level voltage must be above the specification improved for standard CMOS circuitry with noise immunity stated above as greater than 3.85v. The effects of the leakage current may be tested by measuring the open circuit voltage on the device SDI-12 data bus at the highest expected operating temperature. The result must be less than .225v. Care must be given to the selection of a volt meter such that its own leakage current is much less than the upper limit of 0.6 uA for the circuit under test.

This second test does not verify the presence of a grounding resistor, since the input impedance of the voltmeter may be sufficient to overcome low circuit under test leakage currents. A third test adding a 10meg ohm pull-up resistor between the data bus and +5v to the open circuit data bus voltage test using a volt meter with input impedance >= 1 G ohm could verify this. The test could verify the idle bus voltage does not increase more than 0.17v when the 10meg ohm resistor is switched in. A forth test of the driven mark level could be made with an upper limit of .225v as in the leakage test.

The Technical Committee may firm up the specification on the data line off impedance, based on information in Rick's article.

SDI-12 SUPPORT GROUP MEMBERS

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CAMPBELL SCIENTIFIC (CANADA), CORP.
CLIMATRONICS COPORATION
COASTAL ENVIRONMENTAL SYSTEMS
DESIGN ANALYSIS ASSOICATES, INC.
ENDECO/YSI
ENVIRONMENTAL SYSTEMS CORPORATION
FCI ENVIRONMENTAL, INC.
FOREST TECHNOLOGY SYSTEMS, INC.
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HYDROLOGIC
IN-SITU, INC.
JGS ENTERPRISES, INC.
LEUPOLD & STEVENS
MET ONE NORTHWEST, INC.
MINDATA PTY LTD
NR SYSTEMS, INC.
PAROSCIENTIFIC, INC.
RAINWISE
RITTMEYER LTD.
SETRA SYSTEMS, INC.
SIGNAL ENGINEERING, INC.
SLOPE INDICATOR CO.
SOLOMAT
SOUTH FLORIDA WATER MANAGEMENT
SUTRON CORPORATION
TAVIS CORPORATION
TROXLER ELECTRONIC LABORATORIES, INC.
U.S. GEOLOGICAL SURVEY
VITEL, INC.

Proposed Error Checking Scheme

Joe Thurston (Campbell Scientific) has submitted the following article, which proposes an error detection scheme. The Technical Committee may propose adding this scheme as an upgrade to SDI-12.

The sensor response must include a Cyclic Redundancy Check (CRC) calculation if the upper case D (or R) character is replaced with a lower case d (or r).

The CRC calculation is performed on all response characters exclusive of the address and the <cr><lf> characters. The CRC characters are appended to the response as the last field preceding the <cr><lf> characters.

The sixteen bit CRC is converted to three printable ASCII characters. The converted high-order byte (the byte with the most significant nibble of the sixteen bit CRC) is appended first. Table 1 maps the two byte to three byte conversion.

Table 1. Two byte CRC to three byte bit map, where "a" is the most significant bit of the first byte.

	Two Byte Format	Three Byte Format
1st	abcd efgh	0100 abcd
2nd	ijkl mnop	01ef ghij
3rd		01kl mnop

The CRC is derived from the CRC-16 (ANSI) generating polynomial X^16+X^15+X^2+1.

SDI-12
SUPPORT
GROUP
SERIAL DATA INTERFACE AT 1200 BAUD

Membership Dues

Name: ______________________________ Company: ____________________________

Address: ____

City, State, Zip: ____

Phone: ____________ Fax: _____________ e-mail: ______________________________

Dues are $120.00 per year. *Membership dues are not deductible as charitable contributions for Federal Income Tax purposes*. Make your check payable to the SDI-12 Support Group and return this page to:

SDI-12 Support Group
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Feedback Sheet

1. Do you agree to increase the size of the technical committee from nine to twelve members? Yes ☐ No ☐

2. Do you see a need for a wireless SDI-12 Specification? Yes ☐ No ☐

3. Would you like the SDI-12 Support Group to provide a logo/sticker to indicate product compliance with SDI-12? Yes ☐ No ☐

4. Can we add a link to your web from on the SDI-12 Support Group's web page? Yes ☐ No ☐

If yes, what is your web page address? ____

5. Do you have any comments about the proposed error checking scheme (see Joe Thurston's article on page 5)? _________

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