SSI Technologies - Application Note AT-AN5

Acu-Trac™ Ultrasonic Level Sensors

RS-485 Mode Messaging

General

SSI's Acu-Trac™ ultrasonic level sensors broadcast and receive commands over a standard TIA/EIA RS-485 serial data bus enabling the sensors to communicate and share data with other modules located on the data link.

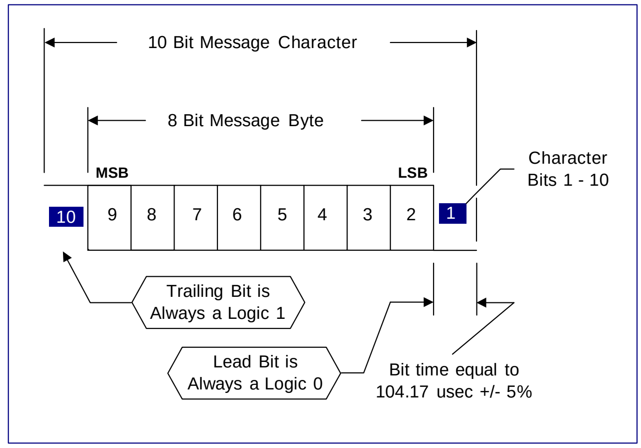
The RS-485 data link is a serial data link meaning that messages are transmitted one bit at time in sequence until the entire message has been completed. Idle states, I.E. the down time in-between messages is used to signal the bus availability to other transmitting nodes within the network.

The Acu-Trac™ ultrasonic level sensor is designed to communicate at a rate of 9600 baud. During normal operation, the Acu-Trac™ ultrasonic level sensor will broadcast a 19 byte volume measurement message every 0.50 seconds consuming approximately 4% of the available data link bandwidth.

For illustration purposes, all the message drawings depicted herein are referenced from the transmitting nodes perspective with the beginning of the message located on the drawing's right hand side and the message end located on the drawing's left.

Message & Character Construction

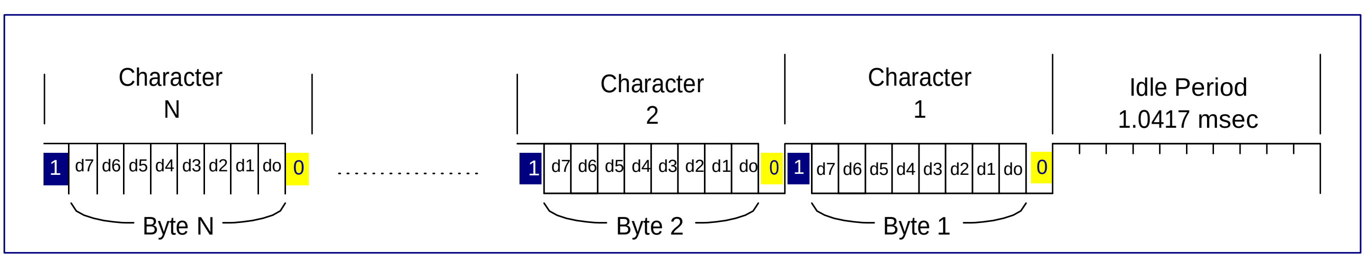
Messages are formatted into a series of characters, 10 bits each, which are strung together to create a complete message as shown in the *RS-485 Message Construction* drawing below.



Character Definitions

Each character within the message string is comprised of a leading bit, or start bit, an 8 bit message byte followed by the trailing bit or stop bit. The start bit is always at a logic low level (0), while the trailing bit is always at a logic high level (1). The message byte is transmitted with the LSB, least significant bit, first followed in sequence with bits 2, 3, 4 and so on. See the above drawing titled *Character Definitions*.

The bit time for each character bit is 104.17 µsecs +/- 0.5% which effectively yields a baud rate of 9600 bits per second.



RS-485 Message Construction

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Idle State

The bus will return to a logic level high (1) when all of the data link transmitters are turned off as measured at the input to the bus receiver(s); this is called the idle state.

As mentioned previously, the idle state in-between messages serves as a delimiter on the RS-485 bus. Any transmitting node on the bus must first verify that this idle state has existed for at least 10 bit times or 1.0417 msecs before initiating a new message transmission.

A receiving node that has lost synchronization and cannot distinguish between the message stop bit and any other message high bit, can use the idle period to reestablish synchronization.

Re-synchronization is achieved by noting the receipt of 12 consecutive high logic bits. In the absence of errors, the first logic 0 following the receipt of 12 consecutive high bits is the start bit of the next message.

SSI Message Format

All messages transmitted and received by the Acu-Trac™ ultrasonic level sensor family follow the format depicted on the bottom of this page and described herein.

The first message byte, Message Transmitter Identification, is always the identification number of the device broadcasting the message. The Acu-Trac™ ultrasonic level sensor uses 143 for its identification number and communicates with and responds to commands from transceiver node identification number(s) ≥ 128. (We use 177 in our example)

The second message byte, Service Code, is always 254 for Acu-Trac™ ultrasonic level sensor messages.

The third message byte, Message Receipt Identifier, provides the identification number for the intended message recipient. The Acu-Trac™ ultrasonic level sensor will only respond to commands in which the third byte, Message Receipt Identifier, is set to 143 designating the identification number for the Acu-Trac™ ultrasonic level sensor family.

The fourth message byte defines the Number of Remaining Characters in the message exclusive of the checksum. If the fourth byte is a one (1) then the message is a command and contains no data. If the fourth byte is greater than 1 then the sixth message byte will contain the number of data elements in the transmission.

The fifth message byte, Message Identifier, defines what the message is and/or is intended to accomplish. ACU-TRAC's™ ultrasonic level sensor family responds to the following message identifiers:

The Acu-Trac™ ultrasonic level sensor will use the following message identifiers in its transmissions:

Identifier	Message
190	Measurement Broadcast
193	Programming/Diagnostic Data Broadcast

The ultrasonic level sensor will also respond to the following message identifiers used as commands.

Identifier	Message
192	Programming Command
213	Diagnostic Command

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The sixth message byte, Number of Data Characters, denotes the number of data elements contained which are to follow and is only used in messages which contain data.

Bytes 7 through N-1, Data, are reserved for data characters.

The last message byte, Checksum, is the twos compliment check sum for the entire message exclusive of the checksum and is used to qualify the validity of the message. A simple error detection scheme may be implemented by adding the checksum to the sum of all of the message characters; the 8 bit sum should be zero neglecting any carry(s) generated.

Message Example

The following example describes the process for decoding the ultrasonic level sensor's volume message and how that message would look out on the RS485 bus. A graphical depiction of the message is shown on the next page titled *Volume Measurement Message Example*. In this example, the received message is as follows:

Byte1	Byte 2	Byte3	Byte4	Byte 5	Byte 6	Byte 7
143	**254**	**177**	**14**	**190**	**12**	**1**
Byte 8	Byte 9	Byte10	Byte11	Byte12	Byte13	Byte14
64	**1**	**224**	**48**	**48**	**48**	**51**
Byte15	Byte16	Byte17	Byte18	Byte19		
51	**50**	**55**	**53**	**52**		

The 1st received byte, Message Transmitter Identification, value 143, is the originator of the broadcast, meaning that the message was transmitted by an Acu-Trac® ultrasonic level sensor.

The 2nd byte, Service Code, value 254, is the proprietary service code designation used by SSI for all Acu-Trac® ultrasonic level sensor messages.

The 3rd byte, Message Receipt Identifier, value 177, denotes the intended recipient for the broadcast which is always a transceiver node number ≥ 128.

The 4th byte, Number of Remaining Characters, value 14, is the number of characters remaining in the message.

The 5th byte, Message Identifier, value 190, is the message identifier meaning that the message is a Measurement Broadcast.

The 6th byte, Number of Data Characters, value 12, is the number of data bytes in the message.

The 7th byte, Data, value 1, is the MSB of % of full scale capacity value.

The 8th byte, Data, value 64, is the LSB of the % of capacity value. Therefore the target location as a % of full scale capacity can now be calculated as follows:

% of Capacity = (MSB x 256 + LSB)/800

% of capacity = (1 x 256 + 64)/800

% of Capacity = 40.0%

The 9th byte, Data, value 1, is the MSB of the measurement. Based on the sensor's pre programmed unit scale.

The 10th byte, Data, value 224, is the LSB of the measurement, based on the sensor's preprogrammed unit scale.

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The 11th byte, Data, value 48, is an ASCII representation of the most significant digit of the serial number which is 0.

The 12th byte, Data, value 48, is an ASCII representation of the next digit of the serial number which is 0.

The 13th byte, Data, value 48, is an ASCII representation of the next digit of the serial number which is 0.

The 14th byte, Data, value 51, is an ASCII representation of the next digit in the serial number which is 3.

The 15th byte, Data, value 51, is an ASCII representation of the next digit of the serial number which is 3.

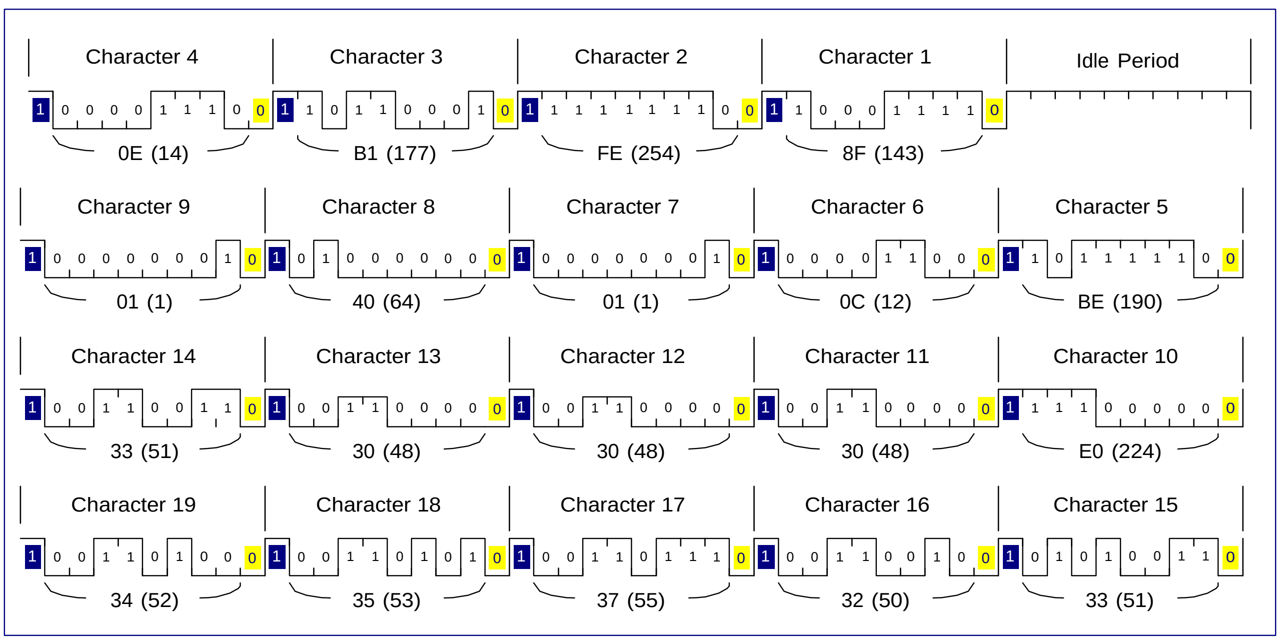
The 16th byte, Data, value 50, is an ASCII representation of the next digit of the serial number which is 2.

The 17th byte, Data, value 55, is an ASCII representation of the next digit in the serial number which is 7.

The 18h byte, Data value, 53, is an ASCII representation of the least significant digit in the serial number which is 5.

Based on received message bytes 11 through 18 we can now assemble the serial number as follows:

Byte11	Byte12	Byte13	Byte14	Byte15	Byte16	Byte17	Byte18
0	0	0	3	3	2	7	5



Distance Mesurement Message Example

Serial number = 00033275

Knowing the serial number allows one to look up the sensor's operating mode and full scale range using a cross referenced table of values linked to the sensor's serial number.

For the purposes of this example we are using an Acu-Trac™ ultrasonic level sensor with a full scale range of 30 inches operating in the rectilinear mode. To summarize:

Sensor serial:	00033275
Operating Mode:	Rectilinear
Full Scale range:	150 gallons

Based on this data, we can now determine the actual volume in the tank using the measurement LSB, value 01, and MSB, value 224, contained within message bytes 9 and 10. The volume in the tank can be derived as follows:

Volume = (MSB x 256 + LSB)/8

Volume = (1x256 +224)/8 gallons

Volume = 60.0 gallons

The last byte in the message is the Checksum, value 52 or in hex 0x34. The checksum provides a convenient method for checking the validity of the message by using the two's compliment sum of all of the data characters ignoring any carries generated along the way. For example:

Calculate the Sum of all the message bytes, Bytes1 through 19 = 1536

Convert 1536 to Hexadecimal = 0x600

Ignore the carries using only the least significant byte = 0x00 or 0 decimal

The result from the calculation was 0 meaning that the message was correctly received.

To summarize we can conclude from this message that the tank fitted with Ultrasonic level sensor serial number 00033275 has 60 gallons left.

Transceiver Electrical Characteristics

The following electrical characteristics and conventions refer to the Serial Bus Node Diagram located on the next page.

Positive logic is used when referring to the state of transmitted inputs and receiver outputs. The bus is considered to be at a logic high (1) state if the A line is at least 0.2 volts more positive than the B line. Conversely the bus is considered to be at a logic low (0) state whenever the A line is 0.2 volts below that of the B line. The transceiver circuit utilizes a standard RS-485 transceiver connected to drive the differential data bus into the logic low (0) state. The logic high state is controlled by the 4.7 k-ohm pull up resistor and the 4.7 k-ohm pull down resistors.

EMI suppression is facilitated by the 1nf capacitor in conjunction with the 47 ohm series resistor located on each line.

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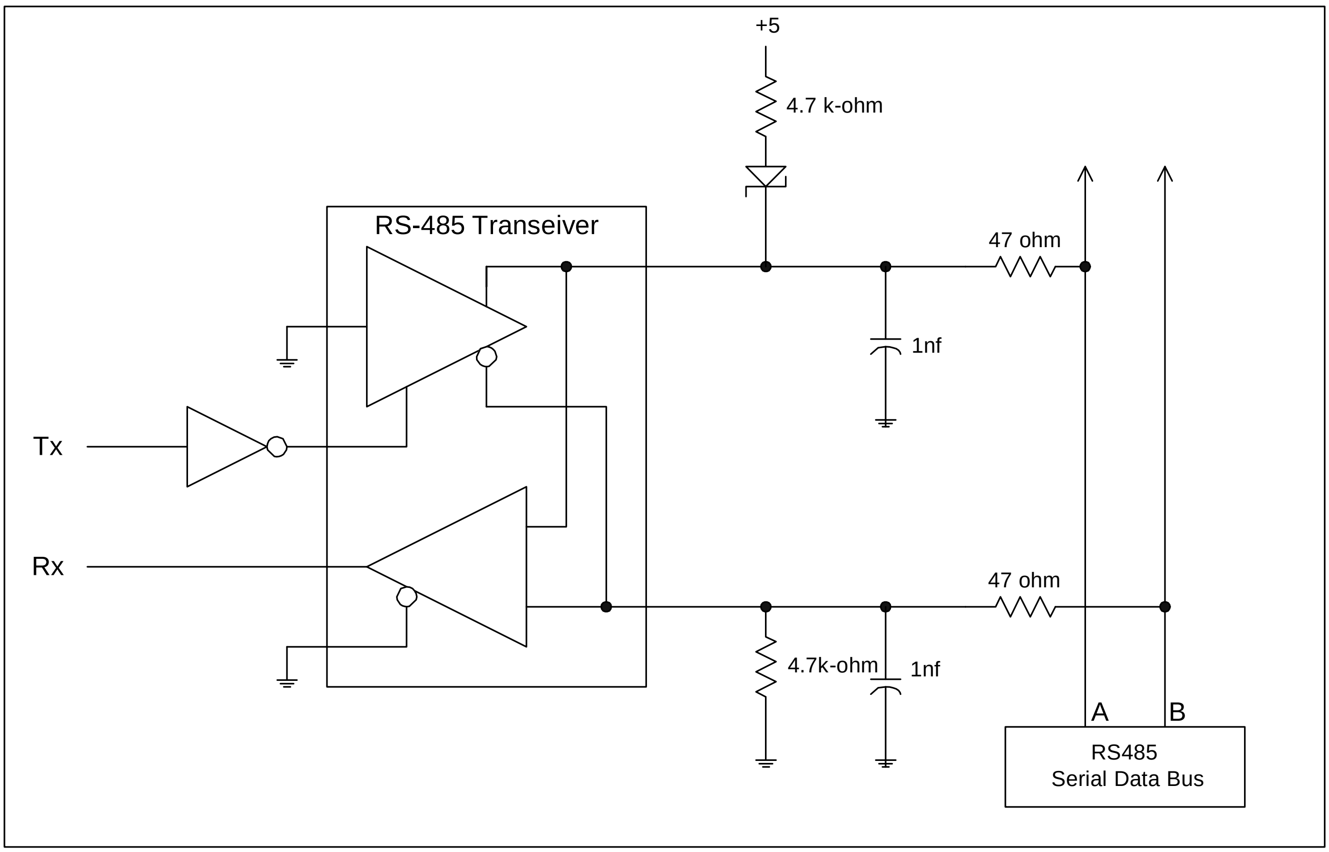

Serial Bus Node Diagragm

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RS-485 Messages

The Acu-Trac™ ultrasonic level sensors broadcast and receive commands over the RS-485 serial data link enabling the sensors to communicate to and share data with other modules located on the bus.

The ultrasonic level sensor messages can be loosely organized as follows:

1) Setup & Programming Commands
2) Timed Broadcasts

The Setup & Programming Commands are used to program the ultrasonic level sensor for the particular tank's size shape and installation.

Note: These commands can only be issued and responded to with one sensor enabled on the data link.

The Timed Broadcasts convey measurement data from the ultrasonic level sensor(s) to other modules on the bus. Each sensor consumes approximately 5% of the available 9600 baud bus capacity and, thus, up to 10 sensors may be connected on to a single bus.

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Setup & Programming Commands

Analog Gauge Drive Transfer Function Parameters

Read Command	MID	254	143	3	192	1	130	chk						
Write Command	MID	254	143	11	192	9	130	D1	D2	- - -	D8	chk		
Response	143	254	MID	11	192	9	130	D1	D2	- - -	D8	chk		

Where

MID 8 bit transmitting station identification number, must be 128 or greater.
D1 D2 16 bit DAC Output Voltage @ Capacity Maximum Limit @ 10.04 mv per bit,
D3 D4 16 bit DAC Output Voltage @ Capacity Minimum Limit @ 10.04 mv per bit
D5 D6 16 bit Capacity Maximum Limit 0.125% per bit, (msb first lsb last)
D7 D8 16 bit Capacity Minimum Limit 0.125% per bit, (msb first lsb last)

Measurement Filter Timer Constant

Read Command	MID	254	143	3	192	1	131	chk	
Write Command	MID	254	143	4	192	2	131	D1	chk
Response	143	254	MID	4	192	2	131	D1	chk

Where

MID 8 bit transmitting station identification number, must be 128 or greater.
D1 Measurement Filter Time Constant at 0.8 seconds/bit

Tank Capacity & PWM Duty Cycle Parameters

Read Command	MID	254	143	3	192	1	123	chk		
Write Command	MID	254	143	7	192	5	123	D1	D2	chk
Response	143	254	MID	6	193	4	D1	D2	chk	

Where

D1 D2 16 bit Tank volume in gallons, (msb first lsb last)

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Tank Size, Shape, and Measurement Mode

Read Command	MID	254	143	3	192	1	129	chk				
Write Command	MID	254	143	16	192	14	129	D1	D2	- - -	D13	chk
Response	143	254	MID	16	192	14	129	D1	D2	- - -	D13	chk

Where

D1 D4 Tank Diameter/Depth 4 byte floating point value in inches, (msb first lsb last)

D5 D8 Tank air gap 4 byte floating point value in inches, (msb first lsb last)
D9 D12 Tank width 4 byte floating point value in inches, (msb first lsb last)
D13 Measurement operation mode selection where,

High Nibble Analog output selection 1 = Voltage & 2 = Current loop
Low Nibble Measurement mode, 0 = Linear distance, 1 = Cylindrical level & 2 = Rectilinear level

Timed Broadcasts

Measurement Broadcast

Request	None									
Broadcast	143	254	14	190	12	D1	D2	- - -	D12	chk

Where
D1 D2 16 bit % of capacity value @ 0.125 % per bit, (msb first lsb last)
D3 D4 16 bit measurement value, (msb first lsb last)
D5 D12 8 byte sensor serial number in ASCII

Broadcast Rate,
Message is transmitted 2 times per second.

Additional References

TIA/EIA – 485-A Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems. March 1998

SAE J1708 Serial Data Communications Between Microcomputer and Systems in Heavy-Duty Vehicle Applications. October 1993

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