INTERFACE DESIGN SPECIFICATION

BETWEEN

LBV MOTHERBOARD

AND

THRUSTER MOTOR CONTROLLER

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TABLE OF CONTENTS

LIST OF TABLES

Table **Title** **Page**

1. INTRODUCTION

1.1 PURPOSE

This document specifies the I2C interface between the LBV Motherboard and the Thruster Motor Controller. The LBV motherboard provides an interface to the operator's control console and the Thruster Motor Controller provides an interface to the thruster motor. The LBV Motherboard/Thruster Motor Controller interface provides the necessary link for the operator to control the LBV thrusters.

1.2 RESPONSIBILITY

The responsibility for preparation and maintenance of this document belongs to SeaBotix Inc. Engineering Department. Changes to this document shall be in accordance with established procedures.

1.3 SCOPE

This Interface Design Specification (IDS) provides the information required for the design of the computer programs which control the exchange of data across the interface, and for configuration control of the LBV Motherboard/Thruster Motor Controller interface. As such, it is a record of the agreed upon and approved interface control techniques, message format and contents, timing requirements, and disposition of exchanged data.

2. APPLICABLE DOCUMENTS

2.1 GENERAL

The documents applicable to this IDS are listed in Table I.

TABLE I. APPLICABLE DOCUMENTS

Document	Title
Integrated Circuits	Integrated Circuits Data Handbook, I2C Peripherals for Microcontrollers, Philips Semiconductors
PIC17C7XX Data Sheet	PIC17C7XX Data Sheet, High Performance 8-bit CMOS EPROM Microcontrollers with 10-bit A/D
PIC18F4431 Data Sheet	**PIC18F2331/2431/4331/4431 Data Sheet** 28/40/44-Pin Enhanced Flash Microcontrollers with nanoWatt Technology, High Performance PWM and A/D

3. INTERFACE MESSAGE SUMMARY CROSS INDEX

3.1 GENERAL

This section is not needed in this IDS.

4. FIELD DEFINITION LIST

4.1 GENERAL

This section is not needed in this IDS.

5. NARRATIVE MESSAGE FLOW TABLE

5.1 GENERAL

This section is not needed in this IDS.

6. INTERCOMPUTER COMMUNICATIONS

6.1 General

This section describes the interface between the LBV Motherboard and Thruster Motor Controller. It describes the hardware and software of the system interface, as well as supported protocols.

6.2 Hardware

The LBV Motherboard and the Thruster Motor Controller may use any processor that conforms to the I2C interface specification.

The Thruster Motor Controller shall be capable of setting 102 discreet speed settings into the motor in both the forward and reverse directions. The forward direction shall turn the motor shaft in the counter-clockwise direction as viewed from shaft end. The reverse direction shall turn the motor shaft in the clockwise direction as viewed from shaft end.

The Thruster Motor Controller shall be capable of detecting water, ground fault, overtemp, stalled motor, or hall sensor (if applicable) errors.

6.3 Communication Protocols

The hardware and software employed in the support of this interface must support the industry standard I2C mode of operation.

6.4 Interface Initialization

6.4.1 LBV Motherboard Application

Upon power-up, the LBV Motherboard shall configure the I2C interface for master I2C mode at a clock rate of 100kbit.

6.4.2 Thruster Motor Controller Application

Upon power-up, the Thruster Motor Controller shall configure the I2C interface for slave I2C mode. The Aveox and Legacy Seabotix Thruster Motor Controllers' slave address is 0x54, therefore 0x54 signals a write command from the master and 0x55 signals a read command from the master. The Seabotix Thruster Motor Controller slave address is 0x52, therefore 0x52 signals a write command from the master and 0x53 signals a read command from the master.

6.5 Interface Shutdown

6.5.1 LBV Motherboard Application

No special processing is necessary.

6.5.2 Thruster Motor Controller Application

No special processing is necessary.

6.6 Software

The following subsection specifies the conventions, data transfer procedures and timing requirements which shall be observed during communications between the LBV Motherboard and Thruster Motor Controller.

6.6.1 Normal Data Exchange

After power-up, the Thruster Motor Controller shall be ready to receive data from the LBV Motherboard and respond with the appropriate data as described in Section 8.

Upon receipt of the slave address write command, the Thruster Motor Controller shall configure to read the remaining bytes in the LBV message described in Section 8. In the event of an invalid checksum being received, the incoming message shall be discarded.

Upon receipt of slave address read command, the Thruster Motor Controller shall send the motor controller status as described in Section 8.

6.6.2 Error Recovery Procedures

In the event of an error, the LBV Motherboard and the Thruster Motor Controller shall ensure that their respective applications do not lock up the I2C bus. The Thruster Motor Controller shall ensure that it never holds the clock and/or data lines low except during normal communications with the LBV Motherboard.

7. UNIQUE DATA UNIT DESCRIPTION

7.1 General

This section has been purposely left out due to the redundancy of this section to that provided in Section 8.

8. MESSAGE DESCRIPTIONS

8.1 GENERAL

This section provides a description of the format and content of each message transmitted across the LBV Motherboard/Thruster Motor Controller I2C interface. The technical data of each message is contained in the message format chart. The format and description conventions are as follows:

1. Message Format Chart - shows the position of each field carried by the message (by word and bit location).
    a) The message format is a visual representation of the data fields which comprise the message, arranged in word number sequence and by field (bit location) within each word. Bit numbers (locations) are presented in decimal at the top of the format. Word numbers, starting with word zero, are presented in decimal at the left side of the format. Field locations are indicated by abbreviated names (letters) within the format. A field that represents a constant will show the value in decimal unless otherwise stated. A field that is not used in the message is designated by an elongated dash. These fields must be set to zero by the sending program, however the receiving program must not assume these fields are zero. This allows the fields to be used for future interface updates. In sending and receiving programs, the elongated dash indicates that the field is available for other use. The size of the field is determined by the location of a field separator. The number of bits from either the beginning of a word or a field separator to either another field separator or ending of a word defines the field size. The Least Significant Bit (LSB) of a field is always the lowest bit number of a field in a word.
    b) Additional information, such as message identification, name, source, destination, purpose, timing constraints and remarks, are provided. The interdependency of fields within the message (if any) will be discussed in the message Remarks.
2. Message Description Tables – The message description tables describe each message, in word number and field location sequence, down to the bit level with a tabular representation of all data fields contained in the message as follows:
    a) Field Name/Symbol - The assigned functional name, symbolic representation (mnemonic), and unique data unit (if applicable) of the data field. When it is necessary to make some comment about an unnamed field (constant or unused), the field will be identified by bit position.
    b) Word - Positional information concerning the data field is identified by referencing the word number. By knowing the number of the word containing the data field, the Message Format Chart can be examined to determine the location and size of the data field.

c) Data Type - The terminology used to identify the specific data type is presented in the following table.

Terminology	Data Type
Character Data	
Char	ASCII Character (8 bits)
Floating Point Data	
Float	Float (32 bits)
Double	Double Precision (64 bits)
Integer Data	
Char	Integer (8 bits) signed
UChar	Integer (8 bits) unsigned
Short	Integer (16 bits) signed
UShort	Integer (16 bits) unsigned
Integer	Integer (32 bits) signed
UInteger	Integer (32 bits) unsigned

d) Range of Value – The data field type and expected upper and lower limits of the data field.

i) The limits, defining valid ranges of values to be transmitted, are expressed in decimal unless otherwise stated. When the number is a hex number, it will be shown with a "16" subscript. Where necessary, the meaning of a number is explained under the Remarks column. Where there is only one value, the word "fixed" appears in the column along with the constant value.

ii) When the range of value is limited only by the capacity of the character, integer, and floating point data types, the terms Float, Double, Integer, UInteger, Long, ULong, Short, and UShort are used rather than repeating the minimum and maximum values for each occurrence.

e) Remarks - Any special considerations or amplification of the data field. When enumerated data is used, the meaning will be explained under the associated remarks column. ON or SET conditions which are indicated by a single bit quantity shall be represented by a 1 unless otherwise indicated. OFF or NOT SET conditions which are indicated by a single bit quantity shall be represented by a 0 unless otherwise indicated. When single bit quantities are utilized for other states or conditions, they are described in the remarks column. Whenever an enumeration is marked "NA" (not applicable) the message transmitter may set the enumeration but the message receiver will not interpret the enumeration.

Units - The increment of metering the parameter, such as degrees, yards, seconds, if applicable will be shown in the remarks column.

Scaling - Applicable to a fixed point binary data field only. The scaling specifies the number of bits before and after the binary point. For example, a one byte temperature measurement with the binary point between bit 0 and 1 would be defined to have a scaling of 7-1. If the units for defining the scaling is other than binary, then the units, such as Octal or Hex, must be identified. Scaling if applicable will be shown in the remarks column.

8.2 Order of Precedence

In the event of a conflict with information within this document the information found in section 8 shall take precedence.

8.3 LBV Motherboard To Thruster Motor Controller Message

8.3.1 Aveox/Legacy Seabotix Motor Controller

Message Number/Name: MT-54, Thruster Motor Controller Order

Source: LBV Motherboard

Destination: Thruster Motor Controller

Message Purpose: This message is used to order the Thruster Motor Controller to the desired speed.

Timing Constraints:
1. This message shall be sent to the Thruster Motor Controller whenever the LBV motherboard requires an update to the previously ordered thruster speed. This will normally occur upon receipt of motor control message from the control console.

Message Format Chart

Word	0 7
0	MT=54_{16}
1	SPEED
2	INFO
3	CSUM

Message Description Table

Field Name/Symbol	Word	Data Type	Range of Values	Remarks
Message Type /MT	0	UChar	54_{16} fixed	Indicates the message. This value addresses the thruster.
Thruster Speed value /SPEED	1	UChar	19_{16} – $E6_{16}$	Indicates the ordered speed of the thruster. $7F_{16}$ and 80_{16} are zero speed. 81_{16} - $E6_{16}$ are forward speeds with $E6_{16}$ being max forward speed. $7E_{16}$ - 19_{16} are reverse speeds with 19_{16} being max reverse speed.
Additional Info/INFO	2	UChar	0 - FF_{16}	Future growth. Currently set to 100. Was intended to inform thruster to output no more than this value as a percentage of power, regardless of ordered speed. This would allow the thruster to increase speed of thruster up to ordered value as current reduces due to vehicle acceleration/deceleration.
Checksum /CSUM	3	UChar	0 - FF_{16}	Indicates the calculated eight bit unsigned addition without carry of the above fields.

Remarks:
1. None.

8.3.2 SeaBotix Motor Controller

Message Number/Name: MT-52, Thruster Motor Controller Order

Source: LBV Motherboard

Destination: Thruster Motor Controller

Message Purpose: This message is used to order the Thruster Motor Controller to the desired speed.

Timing Constraints:

1. This message shall be sent to the Thruster Motor Controller whenever the LBV motherboard requires an update to the previously ordered thruster speed. This will normally occur upon receipt of motor control message from the control console.

Message Format Chart

Word	0 7
0	MT=52_{16}
1	SPEED
2	INFO
3	CSUM

Message Description Table

Field Name/Symbol	Word	Data Type	Range of Values	Remarks
Message Type /MT	0	UChar	52_{16} fixed	Indicates the message. This value addresses the thruster.
Thruster Speed value /SPEED	1	UChar	19_{16} – $E6_{16}$	Indicates the ordered speed of the thruster. $7F_{16}$ and 80_{16} are zero speed. 81_{16} - $E6_{16}$ are forward speeds with $E6_{16}$ being max forward speed. $7E_{16}$ - 19_{16} are reverse speeds with 19_{16} being max reverse speed. Max forward and reverse speeds are currently set to 4500 rpm for brushless motors. Values are just proportional to PWM value for brushed motors.
Additional Info/INFO	2	UChar	0 - FF_{16}	Future growth. Currently set to 100. Was intended to inform thruster to output no more than this value as a percentage of power, regardless of ordered speed. This would allow the thruster to increase speed of thruster up to ordered value as current reduces due to vehicle acceleration/deceleration.
Checksum /CSUM	3	UChar	0 - FF_{16}	Indicates the calculated eight bit unsigned addition without carry of the above fields.

Remarks:

1. None.

8.4 Thruster Motor Controller To LBV Motherboard Message

8.4.1 Aveox/Legacy Seabotix Thruster Motor Controller

Message Number/Name: MT-55, Thruster Motor Controller Order

Source: Thruster Motor Controller

Destination: LBV Motherboard

Message Purpose: This message is sent to identify the status of the Thruster Motor Controller.

Timing Constraints:
1. This message shall be sent to the LBV Motherboard upon receipt of the Thruster Motor Controller read command (55_{16}) from the LBV Motherboard.

Word	7 0
0	MT=55_{16}
1	STATUS
2	MAX POWER
3	CSUM

Field Name/Symbol	Word	Data Type	Range of Values	Remarks
Message Type /MT	0	UChar	55_{16} fixed	Indicates the message. This value is the same value that addressed the thruster for the read operation and is repeated back to the LBV motherboard.
Status/STATUS	1	UChar	Coded	**Bits 5-7** Indicates the revision number of the Thruster Motor Controller software. 0 – original thruster software, all bits zero (for backward compatibility) 1 – brushless DC software (first revision - Aveox), bit 5 set 2 – brushed DC software (first revision – Seabotix Legacy), bit 6 set 4-- brushed DC software(revision 4), bit 7 set **Bit 4** Indicates the water detect status. 0 – no water detected, bit not set 1 – water detected, bit set **Bits 0-3** Indicates the status of the thruster. Bit is set when error occurs. Bit 0 -- overtemp Bit 1 -- stalled motor Bit 2 -- hall sensor error Bit 3 -- ground fault error

Max Power/MAX POWER	2	UChar	0 - FF_{16}	For brushless DC software (see STATUS byte), indicates the current being drawn by the motor. The units for this value shall be in tenths of amps. i.e. a value of 12 (decimal) will represent 1.2 amps. For brushed DC software (see STATUS byte), indicates the power currently set into the thruster. This value should be the same as the SPEED value commanded by the LBV motherboard, except when the Thruster Motor Controller has determined that the SPEED value commanded is too high (possibly due to current restrictions, entanglement, etc.), at which time it should reflect the speed value set into the motor.
Checksum /CSUM	3	UChar	0 - FF_{16}	Indicates the calculated eight bit unsigned addition without carry of the above fields.

Remarks:

1. In the event of an error being reported in the STATUS field (bits 0-4), the thruster motor controller shall continue to communicate with the LBV motherboard.
2. In the event of a water detect error, the thruster motor controller shall discontinue driving the motor. This error shall not be cleared until power is cycled on the thruster motor controller.
3. In the event of an overtemp error, the thruster motor controller shall discontinue driving the motor. The brushless motor controller shall set the overtemp fault at 110C and clear the fault at 100C, at which time the thruster motor controller may continue driving the motor.
4. In the event of a stalled motor error, the thruster motor controller shall discontinue driving the motor. The brushless motor controller shall set the stalled motor fault when the duty cycle is above 8% and less than 3 hall sensor pulses are detected within 400ms.
5. In the event of a hall sensor error, the thruster motor controller shall discontinue driving the motor. This error may be cleared when the thruster motor controller detects the hall sensors are in a normal state.
6. In the event of a Ground Fault error, the thruster motor controller shall discontinue driving the motor. This error shall not be cleared until power is cycled on the thruster motor controller. This error occurs when the resistance between the water detect sensors drops below 100 kilo-ohms.

8.4.2 SeaBotix Motor Controller Thruster Motor Controller To LBV Motherboard Message

Message Number/Name: MT-53, Thruster Motor Controller Order

Source: Thruster Motor Controller

Destination: LBV Motherboard

Message Purpose: This message is sent to identify the status of the Thruster Motor Controller.

Timing Constraints:
1. This message shall be sent to the LBV Motherboard upon receipt of the Thruster Motor Controller read command (57_{16}) from the LBV Motherboard.

Word	7 0
0	MT=53_{16}
1	STATUS
2	FAULT
3	CURRENT
4	SPEED
5	TEMPERATURE
6	CSUM

Field Name/Symbol	Word	Data Type	Range of Values	Remarks
Message Type /MT	0	UChar	53_{16} fixed	Indicates the message. This value is the same value that addressed the thruster for the read operation and is repeated back to the LBV motherboard.
Status/STATUS	1	UChar	Coded	**Bits 4-7** Indicates the revision number of the Thruster Motor Controller software. 0 – Original thruster software for brushless motor with SeaBotix controller, all bits zero. **Bits 2-3** **Future growth** **Bit 1** 0 - Indicates brushed motor. 1 - Indicates brushless motor. **Bit 0** 0 - Indicates current limited version of the Thruster Motor Controller software. 1 - Indicates non current limiting version of the Thruster Motor Controller software.

Fault/FAULT	2	UChar	Coded	Indicates the fault status of the thruster. Bit is set to indicate fault. Bit 0 – Overtemp Bit 1 – Stalled Motor Bit 2 – Hall Sensor Error Bit 3 – Ground Fault Bit 4 – Water Detect Bit 5 – (future growth) Bit 6 – (future growth) Bit 7 – (future growth)
Current/CURRENT	3	UChar	0 - FF_{16}	For brushless DC software (see STATUS byte), indicates the current being drawn by the motor. The units for this value shall be in tenths of amps. (i.e. a value of 12 (decimal) will represent 1.2 amps).
Speed/SPEED	4	UChar		Indicates the actual speed of the thruster. $7F_{16}$ and 80_{16} are zero speed. 81_{16} - $E6_{16}$ are forward speeds with $E6_{16}$ being max forward speed. $7E_{16}$ - 19_{16} are reverse speeds with 19_{16} being max reverse speed. Max forward and reverse speeds are currently set to 4500 rpm for brushless motors. Values returned is PWM value for brushed motors.
Temperature/ TEMPERATURE	5	UChar		Motor temperature in degrees Celsius. Motor controller temperature for brushed motors.
Checksum /CSUM	6	UChar		Indicates the calculated eight bit unsigned addition without carry of the above fields.

Remarks:

1 In the event of an error being reported in the FAULT field, the thruster motor controller shall continue to communicate with the LBV motherboard.

2 In the event of a Water Detect error, the thruster motor controller shall continue driving the motor. This error occurs when the resistance between the water detect sensors is below one megohm and is an initial warning that there may be water in the thruster and the vehicle should be brought to the surface. If the resistance rises above one mega-ohm the fault flag clears.

3 In the event of a Ground Fault error, the thruster motor controller shall discontinue driving the motor. This error shall not be cleared until power is cycled on the thruster motor controller. This error occurs when the resistance between the water detect sensors drops below 100 kilo-ohms.

4 In the event of a Hall Sensor error, the thruster motor controller shall discontinue driving the motor. This error may be cleared when the thruster motor controller detects the hall sensors are in a normal state.

5 In the event of a Stalled Motor error, the thruster motor controller shall discontinue driving the motor. The brushless motor controller shall set the Stalled Motor fault when the duty cycle is above 8% and less than 3 hall sensor pulses are detected within 400ms.

6 In the event of an Overtemp error, the thruster motor controller shall discontinue driving the motor. The brushless motor controller shall set the Overtemp fault at 110C and clear the fault at 100C, at which time the thruster motor controller may continue driving the motor.