# Rugged Remote Control System with Six Analog Axes, Eight Programmable Buttons, Status LCD, Emergency Stop, and Simple Integration Interface

HRI's Safe Remote Control System is a medium to long-range wireless controller designed from the ground up to enable the safe operation of remote and automated systems. It provides a rugged, ergonomic, and easy to understand controller with a flexible receiver that both implement HRI's proprietary SafetySense™ technology to ensure consistent and reliable control.

## 1. Applications

- Control of remote, tele-operated, semi- or fully autonomous robotic systems where safety and usability are critical.
- Monitoring of fixed or mobile industrial systems requiring sophisticated control and reliable wireless emergency stop capabilities.
- Pan & tilt controls for security and surveillance.

## 2. Key Features (Safe Remote Control – SRC)

- SafetySense™ Secure wireless communications with AES128 encryption and range of 1000+ ft.
  - Frequency bands include 900 MHz, 2.4 GHz (Other bands available)
  - AES256 encryption available upon request
- Direct USB interface for easy integration into existing systems
  - Support for USB HID and HRI proprietary interface
- Six fully proportional analog control axes using hall effect, non-contact controls for rugged and reliable performance
- Very low-latency control response (< 40ms)
- Guaranteed low latency emergency stop response (250ms absolute worst case)
- Eight programmable buttons
- SafetySense™ Active User Sensing for enhanced operator safety
  - Free-fall/drop detection
  - Orientation detection
  - Idle controller detection – automatic pause for unattended controls
- Sunlight-readable graphic LCD display
- Dual vibration functions for non-visual directional feedback
- 1000+ unique system addresses

- 12 hour battery life for continuous use
- Independent pause (graceful stop) and emergency stop (immediate stop) modes
- Flexible USB charging interface
- Protocol enforced remote takeover sequence to prevent accidental control of remote or non-line-of-sight systems
- Real-time status display as well as extensive system information display in menu
- RP-SMA antenna connector
- IP67 (NEMA 4X) rated enclosure
- Designed to meet MIL-STD-810 for ruggedness
- -20°C to 60°C operation
- Dual lanyard attachments for flexible harnessing options

## 3. Key Features (Vehicle Safety Controller – VSC)

- SafetySense™ Secure wireless communications with AES128 encryption and range of 1000+ ft.
  - Frequency bands include 900 MHz, 2.4 GHz (Other bands available)
  - AES256 encryption available upon request
- USB, RS-232 serial, and CAN bus support for flexible system integration options
- Hardware-based SafetySense™ implementation for high reliability, no single point of failure safety implementation
- Differential wired emergency stop input
- Master enable outputs for direct stop of motion control equipment
- 8 to 28 VDC power input
- USB configuration for programming and configuration
- Multiple connector options available
  - RP-SMA antenna connector
  - Mini-CPC 4 pin for USB
  - Mini-CPC 9 pin for Power, Estop I/O, RS232, and CAN interfaces
- IP66 (NEMA 4X) rated enclosure
- -20°C to 60°C operation
- ROS™ and C drivers available to accelerate system software development

## 4. SafetySense™ Technology

SafetySense™ Technology consists of four major system-level technologies that work together to provide the integrator the ability to design systems with consistent and reliable remote operations.

### 4.1. Active User Monitoring

The Safe Remote Control constantly monitors its motion and orientation to determine if the controls are in a safe operating state. The system will be put into a safe state (Pause) if the remote detects free-fall, orientation faults (i.e. the remote is moved to the user's side), or a lack of motion (i.e. the user places the remote on a table). This active detection eliminates the need for traditional operator safety mechanisms such as dead-man switches, which are often defeated by the user. Details of the monitoring capabilities of the SRC-001 are discussed in section 5.3.

### 4.2. System-Level Monitoring

All communication links in the system are designed requiring positive feedback. These heartbeat messages are sent on each link in the system (remote to receiver and receiver to integrator computer) at a rate of 50 Hz. This ensures that any fault in the link between the receiver and remote or integrator computer can be quickly detected.

### 4.3. Hardware Health Monitoring

While the receiver is monitoring the health of both the remote and the user computer, it contains dedicated hardware that is monitoring its internal health. Both firmware-based and independent hardware based watchdog timers monitor the functionality of the receiver firmware. The communication link to the remote is also monitored directly in hardware (independent of the firmware-based monitoring). Finally, the reference clock source, used by this custom hardware block, is monitored by a third independent timer to ensure that is operating within its specifications. A failure in any of these components causes the system to indicate an emergency stop situation.

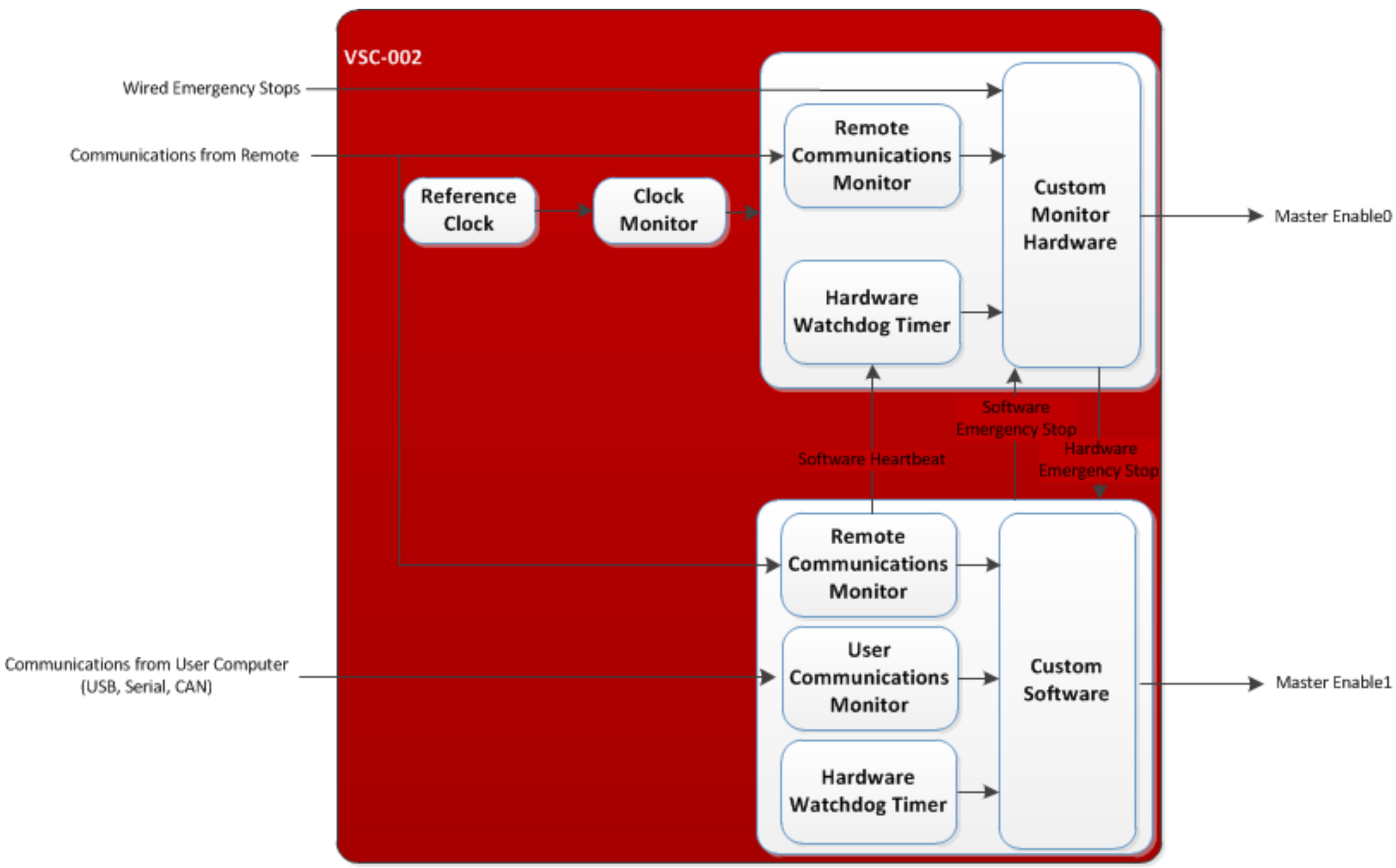


**Figure 1 - Internal Hardware Monitors**

The figure above illustrates the internal structure of the VSC in the SRCS. It is designed from the ground up to ensure that no single point of failure (hardware or software) exists that could cause an unsafe condition to not be caught and indicated by the Master Enable outputs. It is important that system designers pay careful attention in the integration of the VSC with their drive system to ensure that motion will be prevented when the SRCS de-asserts the Master Enable signals.

### 4.4. Consistent User Intervention

While the system is constantly monitoring its health, the remote also provides the operator with the ability to intervene. The SRC-001 has a dedicated emergency stop button, which causes the receiver to indicate an emergency stop in a maximum of 250ms (absolute worst case). This, along with wired emergency stop buttons, gives the system designer significant flexibility.

## 5. Typical Integration Methods

### 5.1. SRC Wireless Integration

Typically, the SRCS is integrated as a simple receiver where the VSC functions as a bridge between the remote and the integrator's control computer. An example of this type of integration is shown in Figure 3.

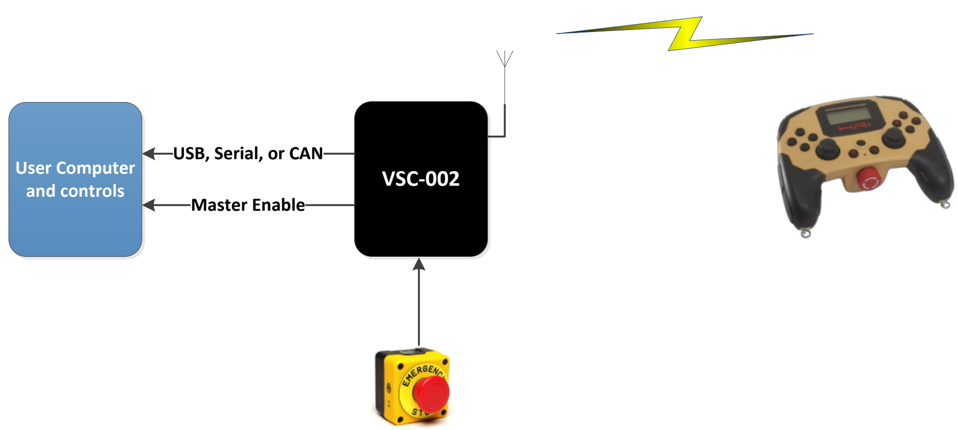


**Figure 2 - Simple Receiver Integration**

Integrating the SRCS as a safety-enabled remote control is the simplest way to achieve remote control capabilities. This configuration enables the user control computer with full access to all functions available on the SRC as well as its operator sensing safety features, both wireless (on the SRC) and wired emergency stops, and hardware and software monitoring of critical communications. Because the VSC does not have direct control over the drive and control system, this configuration relies on the User Computer to ensure that the system is put into a safe state whenever a stop condition is indicated by the VSC (either through a data interface or directly with the Master Enable signal). This integration option is best for cases where the SRCS is being added to an existing system where minimal changes are a design goal.

### 5.2. SRC Wired Integration

The wired version of the SRC can be directly connected to the integrator's control computer. All command and control communication over the USB interface is available in two options, the first is a USB HID Game Controller device, and the second is in the HRI Packet Protocol as described in the SRCS User's Manual. When using the HID Game Controller, the device is implemented as a USB HID device. On most operating systems it will show up as a standard Game Controller device and can be used the same as any off-the-shelf USB game controller including a Logitech or XBox Controller. When using the HRI Packet Protocol over the USB interface, the device is implemented as a CDC device. On most operating systems it will show up as a serial port (*/dev/tty.usbserial*, */dev/ttyACM0*, etc). An example C application is provided that uses the HRI Packet Protocol to communicate with the SRCS over a serial device.

## 6. Operation

All command and control communication to the VSC is over the USB, RS232, or CAN-based interfaces. The specific protocols for each are defined in detail below. The VSC also provides an Emergency Stop interface for hardware based emergency control. Two Master Enable (normally high, low asserted) outputs are provided. Two normally-closed Emergency Stop inputs are also provided, so the VSC can be connected to an existing Emergency Stop interface. If the Emergency Stop input is activated, the Master Enable signals are asserted immediately by VSC hardware.

The Safe Remote Control System has five modes while operating: Searching, Local, Pause, Menu, and Operational. The basic features of these modes are summarized in Table 7. The SRC features 6-axis control, 8 buttons, and an emergency stop but the joystick and button data are only available when the system is in operational mode as described below.

*NOTE: The USB only version of the SRC does not have a "Searching" state, since it is never trying to connect to a VSC. If using a USB only version of the SRC, assume all of the information below referring to the VSC is valid for the data directly from the SRC over the USB device.*

| Mode | Value | Heartbeat | Joysticks | Buttons |
|---|---|---|---|---|
| Searching | 0x01 | E-Stop Indicated | Zeroed | Zeroed |
| Local | 0x04 | Nominal / E-Stop Indicated | Zeroed | Zeroed |
| Operational | 0x09 | Nominal | Active | Active |
| Menu | 0x0A | Nominal | Zeroed | Zeroed |
| Pause | 0x0B | Nominal | Zeroed | Zeroed |

**Table 1: SRCS Modes of Operation**

### 6.1. Searching Mode

Searching mode occurs in several cases. If the SRC is powered on, but cannot connect to a VSC, the LCD display will show it is in Searching Mode. This can occur if the VSC is not powered, or if the SRC is not in range to the VSC. The SRC display will look similar to the following in Searching Mode.

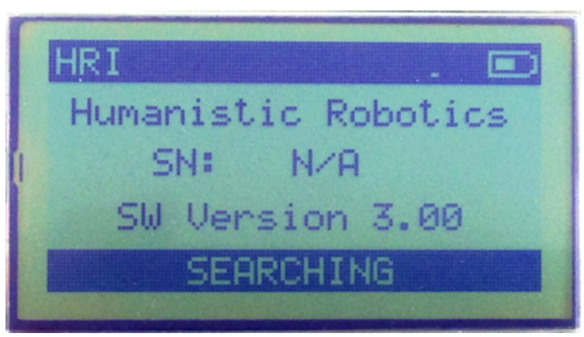


**Figure 3: Searching Mode**

If the VSC is in Searching mode, then it cannot connect to an SRC. This can occur if the SRC is not powered, or the SRC is not in range to the VSC. This is considered an unsafe operating condition because the operator cannot establish a communication link to the vehicle. When the VSC and SRC are not connected, the VSC will continue to output the heartbeat message with an indication that the Emergency Stop is active because of the unsafe condition. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur. The Master Enable outputs from the VSC will also be asserted and can be used to prevent motion.

### 6.2. Local Mode

Local mode occurs when the SRC and the VSC first establish a connection. When in Local mode, the VSC will continue to output the heartbeat message. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur. The Master Enable output from the VSC is de-asserted and can be used to prevent motion. The only transition from Local mode is into Operational mode. The SRC display will look similar to the following in Local Mode.

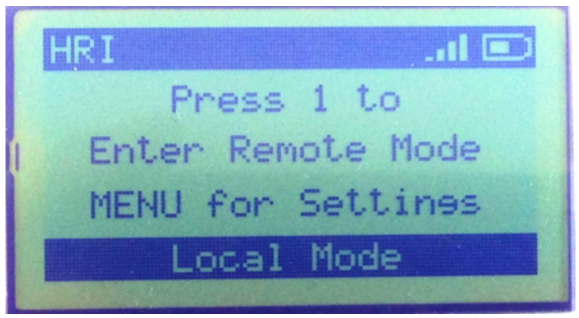


**Figure 4: Local Mode**

Local mode is also entered whenever an Emergency Stop is activated to guarantee the system recovers to a safe state.

### 6.3. Pause Mode

Pause Mode is considered the safe state of the system. When in Pause Mode, the SRC and the VSC have established a communication link, however no motion is intended. The SRC display will look similar to the following in Pause Mode.

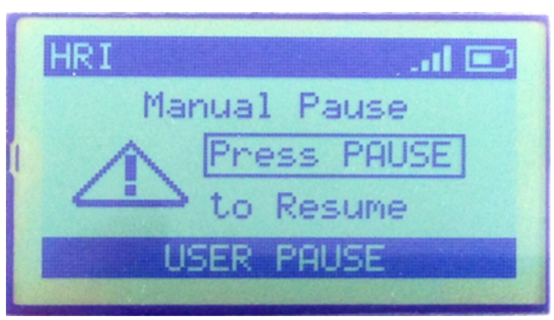


**Figure 5: Pause Mode**

Pause Mode will be entered upon any of the following conditions:

1) Whenever the Pause Button is pressed on the SRC
2) Upon any of the following SafetySense triggers
    a. Orientation Detection
    b. Free-fall Detection
    c. Inactivity Timeout

If the VSC is in Pause Mode, the VSC will continue to output the heartbeat message with an indication that the system is in Pause Mode. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur. The Master Enables output from the VSC will also be de-asserted because this is a safe state even though no motion will occur.

### 6.4. Menu Mode

Menu Mode is used to modify system parameters on the SRC. When in Menu Mode, the SRC and the VSC have established a communication link, however no motion is intended. The SRC LCD display will show it is in Menu Mode.

If the VSC is in Menu Mode, the VSC will continue to output the heartbeat message with an indication that the system is in Menu Mode. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur.

Pressing the Menu Button on the SRC is the only way to enter Menu Mode. The Master Enable outputs from the VSC will also be de-asserted because this is a safe state even though no motion will occur. The SRC display will look similar to the following in Menu Mode.

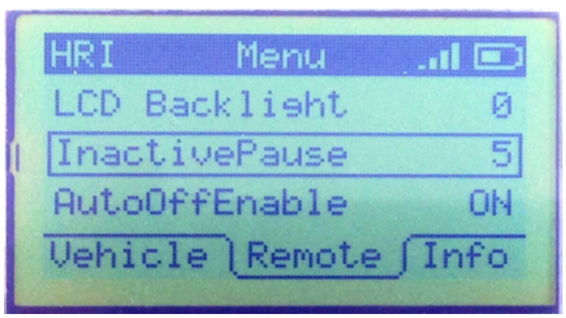


**Figure 6: Menu Mode**

There are three tabs in the menu display, from left to right: Vehicle, Remote, and Info. The Vehicle menu tab displays the 9 user values that can be updated through the VSC interface. The Remote menu tab contains setting specific to the SRC as shown below. The Info menu tab displays related information pertaining to the system, including battery life, software version information, and network ID.

| Menu Item | Description | Values |
|---|---|---|
| *LCD Contrast* | Controls the contrast setting on the LCD screen. | 0 - 16 |
| *LCD Backlight* | Controls the backlight setting on the LCD screen. When set to 0, the backlight is disabled. | 0 - 16 |

| | | |
|---|---|---|
| *InactivePause* | Controls the time before the SRC goes into Pause Mode because of an Inactivity Timeout. The time before going into Pause Mode is the InactiveTime + 1 in minutes. | 0 - 10 |
| *AutoOffEnable* | Controls whether or not the SRC will automatically power off after being inactive for 2 minutes after going into Pause Mode because of an Inactivity Timeout. | ON – OFF |

### 6.5. Operational Mode

Operational Mode is the only state where motion is allowed in the system. When in Operational Mode, the SRC and the VSC have established a communication link, and motion is intended. The SRC LCD display will show it is in Operational Mode. At this point, all joystick movement, and button presses on the SRC will be output from the VSC.

If the VSC is in Operational Mode, the VSC will output the heartbeat message with an indication that the system is operational and the VSC will output the joystick message with all values reflective of commands on the SRC.

Operational Mode is only entered after leaving Local Mode or Pause Mode.

When in Operational Mode, the SRC display has four available modes that are configurable via a feedback key from the API. The default display mode shows data from the GPS module on the SRC including UTC time, Latitude and Longitude. The second display mode allows the user to display four 20-character lines of text using the feedback string functions in the API. These text lines can be updated every 250ms allowing the user to update the entire display once per second if desired. The third display mode will display the first four user defined keys with both the custom text and value. The last display mode will display the first eight user defined keys with only the value updating. For more information regarding custom display updates, refer to the API definition and the example code. The SRC display will look similar to the following in the default Operational Mode.

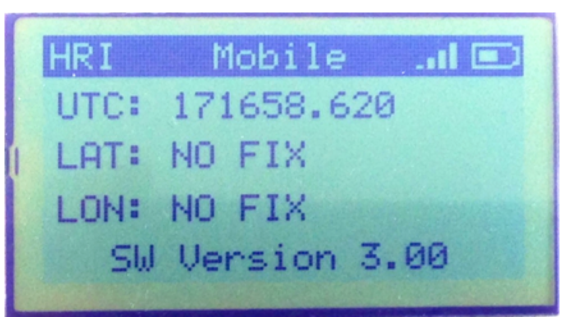


**Figure 7: Operational Mode**

### 6.6. Master Enables

The Master Enable outputs are de-asserted when the system determines that an unsafe condition exists. The LCD display on the SRC will show that the E-Stop is asserted as shown below.

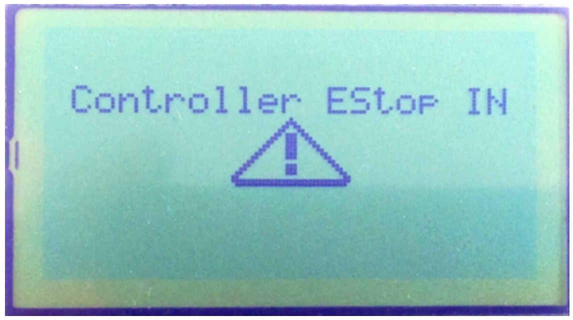


**Figure 8: Emergency Stop Display**

The Master Enables will be de-asserted upon the following conditions:

1) The Emergency Stop Button on the SRC is activated.
2) The External Emergency Stop Input on the VSC is activated.
3) The Emergency Stop Software Input on the VSC is activated.
4) The VSC loses its connection to the SRC.

If the VSC has Master Enable indication asserted, this is considered an unsafe operating condition. It will continue to output the heartbeat message with an indication that the Emergency Stop is active because of the unsafe condition but will return to local mode or searching mode as specified. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur. The Master Enable outputs from the VSC will also be de-asserted and should be used to prevent motion.

The Master Enable outputs will only be asserted once the unsafe condition has been acknowledged and corrected. The system will always revert to Local Mode after an E-Stop condition has occurred.

### 6.7. VSC LED

The VSC LED indicator is tied to the state of the master enable of the VSC and the connection state of the SRC to the VSC.

| LED State | SRCS State |
|---|---|
| *Solid Amber* | VSC in bootloader mode |
| *Solid Red* | SRC not connected or in estop mode |
| *Blinking Red* | SRC connected and VSC estop enabled |
| *Blinking Green* | SRC connected and no estops enabled |

**7. Table 2: VSC LED States**

## 8. Interfacing using HRI Packet Protocol (USB / RS232)

The command and control communication to the VSC is over the RS232 and USB->Serial interface in the HRI Packet Protocol. The serial format is fixed at 8 data bits, 1 stop bit and no parity with a baud rate of 115200. The VSC USB interface is implemented as a CDC device and on most operating systems it will show up as a serial port (*/dev/tty.usbserial*, */dev/ttyACM0*, etc). An example C application is provided that uses the HRI Packet Protocol to communicate with the VSC over a serial device. The example shows to how provide heartbeat and feedback messages to the VSC while receiving joystick, heartbeat and GPS messages from the VSC. The HRI Packet Protocol is a binary protocol designed with error checking, high efficiency and has a well-defined specification. It is used for all communications between the user and the VSC.

### 8.1. Data Types

| Mode | Size |
|---|---|
| uint8 | 0x01 |
| int8 | 0x01 |
| uint16 | 0x02 |
| int16 | 0x02 |
| uint32 | 0x04 |
| int32 | 0x04 |

**Table 3: Packet Protocol Data Types**

### 8.2. Packet Structure

| Byte Offset | Type | Size | Description |
|---|---|---|---|
| 0 | uint16 | 2 | Header |
| 2 | uint8 | 1 | Message Type |
| 3 | uint8 | 1 | Message Length (Size of variable data) |
| 4 | Variable | N | Data Packet |
| N+4 | uint16 | 2 | 16-Bit Checksum |

**Table 4: Packet Protocol Structure**

### 8.3. Message Types

The HRI packet protocol contains all of the messages below. The timing of each message that is output from the VSC can be configured using the "Message Control" packet. The default values for the frequency of the messages are shown below.

| Type | Description | Direction | Enabled | Frequency |
|---|---|---|---|---|
| 0x10 | Joystick | From VSC | Yes | 50 Hz |
| 0x12 | SRC GPS | From VSC | Yes | ~1 Hz |
| 0x20 | Heartbeat | From VSC | Yes | 20 Hz |
| 0x22 | Remote Status | From VSC | No | 1 Hz |
| 0x21 | Heartbeat | To VSC | | 20 Hz |
| 0x23 | Message Control | To VSC | | Aperiodic |

| | | | | |
|---|---|---|---|---|
| 0x30 | User Feedback Set | To/From VSC | Yes | Aperiodic (Max rate 20 Hz) |
| 0x31 | User Feedback Name String | To VSC | | Aperiodic (Should be sent Once, Max rate 4 Hz) |
| 0x32 | User Feedback Get | To VSC | | Aperiodic (Max rate 20 Hz) |

**Table 5: Packet Protocol Message Types**

### 8.3.1. Joystick Message (From VSC)

The joystick message from the SRC includes all 6 axes as well as both D-Pads.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x10 |
| 3 | uint8 | 1 | Message Length | 0x0E |
| 4 | uint16 | 2 | Left X Joystick Value | See Joystick Reference |
| 6 | uint16 | 2 | Left Y Joystick Value | See Joystick Reference |
| 8 | uint16 | 2 | Left Z Joystick Value | See Joystick Reference |
| 10 | uint16 | 2 | Right X Joystick Value | See Joystick Reference |
| 12 | uint16 | 2 | Right Y Joystick Value | See Joystick Reference |
| 14 | uint16 | 2 | Right Z Joystick Value | See Joystick Reference |
| 16 | uint8 | 1 | Left Button Values | See Button Reference |
| 17 | uint8 | 1 | Right Button Values | See Button Reference |
| 18 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 6: Packet Protocol Joystick Message**

### 8.3.2. GPS Message

The GPS message from the VSC contains the GPS location of the specified source in NMEA format.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x12 |
| 3 | uint8 | 1 | Message Length | N |
| 4 | uint8 | 1 | source | 0x01 = SRC |
| 5 | char* | N | String | String of GPS data in NMEA format |
| N+5 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 7: Packet Protocol Heartbeat Message (From VSC)**

### 8.3.3. Heartbeat Message (From VSC)

The heartbeat message from the VSC contains the Emergency Stop indication as well as the current system state.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |

| | | | | |
|---|---|---|---|---|
| 2 | uint8 | 1 | Message Type | 0x20 |
| 3 | uint8 | 1 | Message Length | 0x06 |
| 4 | uint8 | 1 | VSC Mode | See state definitions |
| 5 | uint8 | 1 | Autonomy Mode | 0: User Control<br>1: Shared Control<br>2: Autonomous Control |
| 6 | uint32 | 4 | E-Stop indication | 0 = OK<br>>0 = E-Stop Active<br>(Each bit represents an E-Stop) |
| 10 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 8: Packet Protocol Heartbeat Message (From VSC)**

### 8.3.4. Remote Status Message (From VSC)

The Remote Status message from the VSC contains key information pertaining to the connected remote and the status of the link between the VSC and the remote. *NOTE: These values are not cleared when a connection is lost to the remote device. Make sure to use the state in the heartbeat message to indicate whether or not a remote device is connected*.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x22 |
| 3 | uint8 | 1 | Message Length | 0x06 |
| 4 | uint8 | 1 | Battery Level | Percentage of battery remaining in 10% increments (0-100%) |
| 5 | uint8 | 1 | Battery Charging | 0 = Not Charging, 1 = Charging |
| 6 | uint8 | 1 | Connection Strength (as perceived by VSC) | 0 = Low Connection Strength (intermittent messages, could be disconnected)<br>1 = Medium Strength<br>2 = High Strength |
| 7 | uint8 | 1 | Connection Strength (as perceived by SRC) | 0 = Low Connection Strength<br>1 = Medium Strength<br>2 = High Strength |
| 8 | uint8 | 1 | RSSI (as perceived by VSC) | Reserved for future use |
| 9 | uint8 | 1 | RSSI (as perceived by SRC) | Reserved for future use |
| 10 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 9: Packet Protocol Heartbeat Message (From VSC)**

### 8.3.5. Heartbeat Message (To VSC)

The heartbeat message to the VSC contains the Emergency Stop indication from the user. If the User E-STOP Timeout Key is set, the VSC will use this message as a watchdog for the user computer as well. It will indicate an Emergency Stop condition if the user does not periodically send this message (after a 500ms timeout).

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x21 |
| 3 | uint8 | 1 | Message Length | 0x01 |
| 4 | uint8 | 1 | E-Stop indication | 0 = OK<br>>0 = E-Stop Active |
| 5 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 10: Packet Protocol Heartbeat Message (To VSC)**

### 8.3.6. Message Control Message (To VSC)

The Message Control message to the VSC allows the user to configure which messages are output from the VSC, and how often. The enabled field determines whether or not the message is transmitted. And the interval is defined as the number of milliseconds between transmissions of the message. All of these settings are persistent in EEPROM, so they only need to be configured once by the user. *NOTE: It is not recommended to disable the heartbeat or joystick messages from the VSC*.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x23 |
| 3 | uint8 | 1 | Message Length | 0x04 |
| 4 | uint8 | 1 | Message Type | Which VSC message type to modify |
| 5 | uint8 | 1 | Enabled | Whether or not the message is transmitted. |
| 6 | uint16 | 2 | Interval | Time between transmissions in milliseconds (20 -> UINT16_MAX) |
| 8 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 11: Packet Protocol Heartbeat Message (To VSC)**

### 8.3.7. User Feedback Set Message (To VSC)

The User Feedback message to the VSC allows the user to update values that can be displayed on the SRC. Note, even though this message uses a 32-bit into to transmit data, the SRC can only display 6 characters of information (it is capable of displaying all values in the range of a 16-bit integer). Anything out of range will result in a "XXXXXX" to be displayed.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x30 |
| 3 | uint8 | 1 | Message Length | 0x05 |
| 4 | uint8 | 1 | User Feedback Key | 0-99 |
| 5 | int32 | 4 | User Feedback Value | |
| 7 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 12: Packet Protocol User Feedback Message**

The following keys are currently defined by the system.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. These values should be limited to 16-bit values. |
| 10 | Left Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the left side of the SRC for a small period of time (750ms). |
| 11 | Right Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the right side of the SRC for a small period of time (750ms). |
| 12 | Vibratory Motor Control | Setting this value to 1 will drive both of the vibratory motors of the SRC for a small period of time (750ms). |
| 80 | Inactivity Pause | Controls the time before the SRC goes into Pause Mode because of an Inactivity Timeout. The time before going into Pause Mode is the InactiveTime + 1 in minutes.<br>Valid Values: 0 - 10 |
| 81 | Auto Off Enable | Enables the feature of the SRC to go power-off after 2 minutes past an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 82 | Orientation Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an Orientation Fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 83 | Free-fall Pause Enable | Enables the feature of the SRC to go into Pause Mode because of a Free-fall fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 84 | Inactivity Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 85 | User E-STOP Timeout | Enables the feature of the VSC to enable the watchdog connection to the user computer. If the user computer doesn't continuously transmit heartbeat messages to the VSC, it will indicate an E-STOP condition. (This item is persistent and only needs to be sent once)<br>0 = Disabled (default)<br>1 = Enabled |
| 99 | Display Mode | 0 = Default Display Mode<br>1 = User Text Display Mode (4 Lines)<br>2 = User Key Value / Text Display Mode (4 Values w/ Text)<br>3 = User Key Display Mode (8 Values) |

**Table 13: User Feedback Keys**

### 8.3.8. User Feedback Get Message (To VSC)

The User Feedback Get message to the VSC allows the user to query keys and feedback values from the system. When a valid key is requested, the VSC will queue a User Feedback Set Message back to the user with the requested key/value pair.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x32 |

| | | | | |
|---|---|---|---|---|
| 3 | uint8 | 1 | Message Length | 0x01 |
| 4 | uint8 | 1 | User Feedback Key | 0-99 |
| 5 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 14: Packet Protocol User Feedback Message**

### 8.3.9. User Feedback Message (From VSC)

The User Feedback message from the VSC allows the user to update values in Menu Mode on the SRC that can then be fed back to the control software.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x30 |
| 3 | uint8 | 1 | Message Length | 0x05 |
| 4 | uint8 | 1 | User Feedback Key | 0-99 |
| 5 | int32 | 4 | User Feedback Value | |
| 7 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 15: Packet Protocol User Feedback Message**

The following keys are currently defined by the system.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. These values should be limited to 16-bit values. |

**Table 16: User Feedback Keys**

### 8.3.10. User Feedback Name String Message (To VSC)

The User Feedback message to the VSC allows the user to update the displayed name of the user feedback fields. This message should be sent once during system initialization.

| Byte Offset | Type | Size | Description | Value |
|---|---|---|---|---|
| 0 | uint16 | 2 | Header | 0x1001 |
| 2 | uint8 | 1 | Message Type | 0x31 |
| 3 | uint8 | 1 | Message Length | 0x15 |
| 4 | uint8 | 1 | User Feedback Key | 0-99 |
| 5 | uint8 | 20 | User Key String | Up to 20 characters to be displayed |
| 7 | uint16 | 2 | 16-Bit Checksum | See Checksum Reference |

**Table 17: Packet Protocol User Feedback Message**

The following keys are currently defined by the system for user strings.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. Each value has a corresponding text string name. |
| 90 | Custom Display | In display mode 1, this is the first line of custom text that is displayed. |

| | | |
|---|---|---|
| | Text Line 1 | |
| 91 | Custom Display Text Line 2 | In display mode 1, this is the second line of custom text that is displayed. |
| 92 | Custom Display Text Line 3 | In display mode 1, this is the third line of custom text that is displayed. |
| 93 | Custom Display Text Line 4 | In display mode 1, this is the fourth line of custom text that is displayed. |

**Table 18: User Feedback String Keys**

### 8.4. Joystick Reference

The SRC is a 6-axis controller with three on each hand. The X axis and Y axis are mapped to the thumb stick on top of the SRC, while the Z axis is mapped to the finger stick underneath.


**Figure 9: SRC Joystick Axis Reference**

| Byte | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Byte** | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 0 | Axis Magnitude LSB's | | Positive Status | | Negative Status | | Neutral Status | |
| 1 | Axis Magnitude MSB's | | | | | | | |

**Table 19: Packet Protocol Joystick Reference**

| Status | Definition |
|---|---|
| 0x00 | Not Set |
| 0x01 | Set |
| 0x10 | Error |
| 0x11 | Unavailable |

**Table 20: Packet Protocol Joystick Status Reference**

### 8.5. Button Reference

The Buttons on the SRC are configured in a diamond. The buttons are referenced as those shown below on the left hand side of the controller: Up, Down, Left, Right.

**Figure 10: SRC Joystick Button Reference**

| Byte | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Byte** | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 0 | Left Status | | Up Status | | Right Status | | Down Status | |

**Table 21: SRC Joystick Button Reference**

| Status | Definition |
|---|---|
| 0x00 | Not Set |
| 0x01 | Set |
| 0x10 | Error |
| 0x11 | Unavailable |

**Table 22: SRC Joystick Button Status Reference**

### 8.6. 16-bit Checksum Reference

The 16-bit Checksum used is a variation of the Fletcher 16 checksum for computing a position-dependent checksum devised by John G. Fletcher at Lawrence Livermore Labs in the late 1970s. The objective of the Fletcher checksum was to provide error-detection properties approaching those of a cyclic redundancy check but with the lower computational effort associated with summation techniques.  The algorithm to calculate the checksum is shown below.

```
uint16_t checksum16( uint8_t* data, int count )
{
  uint16_t sum1 = 0;
  uint16_t sum2 = 0;
  int index;

  for( index = 0; index < count; ++index )
  {
    sum1 = (sum1 + data[index]) & 255;
```

```
        sum2 = (sum2 + sum1) & 255;
    }

    return (sum2 << 8) | sum1;
}
```

**Figure 11: Checksum Reference**

# 9. Interfacing using CAN-J1939 Protocol

The CAN Protocol is a binary protocol designed to be compatible with the J1939 specification. It is used for all communications between the user and the VSC.

## 9.1. Packet Structure

The SRCS uses the SAE J1939 basic joystick message to transfer information about the measured status of the X, Y and Z-axis of a joystick, and the state of buttons. The SRCS uses custom SAE J1939 messages to transfer the heartbeat and key-value pair information.

## 9.2. Message Types

| Type | Description | Direction | Frequency |
|---|---|---|---|
| 0x0CFD D633 | Left Joystick - J1939 Basic Joystick Message 1 | From VSC | ~16 Hz |
| 0x0CFD D733 | Left Joystick - J1939 Extended Joystick Message 1 | From VSC | ~16 Hz |
| 0x0CFD D834 | Right Joystick - J1939 Basic Joystick Message 2 | From VSC | ~16 Hz |
| 0x0CFD D934 | Right Joystick - J1939 Extended Joystick Message 2 | From VSC | ~16 Hz |
| 0x0CFD E801 | Heartbeat - J1939 Custom Message | From VSC | 10 Hz |
| 0x0CFD E900 | User Feedback Value - J1939 Custom Message | To VSC | Aperiodic (Max rate 10 Hz) |
| 0x0CFD EA00 | User Feedback String - J1939 Custom Message | To VSC | Aperiodic (Max rate 10 Hz) |

**Table 23: Message Types**

### 9.2.1. Left Joystick - J1939 Basic Joystick Message 1 (From VSC)

The joystick message from the SRC includes the 2 primary axes (X, Y) as well as the 4-button D-Pad.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 2 | Left X Joystick Value | See Joystick Reference |
| 2 | 2 | Left Y Joystick Value | See Joystick Reference |
| 4 | 1 | Unused | 0xFF |
| 5 | 1 | Left Button Values | See Button Reference |
| 6 | 1 | Unused | 0xFF |
| 7 | 1 | Unused | 0xFF |

**Table 24: Left Joystick J1939 Basic Joystick Message 1**

### 9.2.2. Left Joystick - J1939 Extended Joystick Message 1 (From VSC)

The joystick message from the SRC includes the third axis (Z).

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 2 | Left Z Joystick Value | See Joystick Reference |
| 2 | 6 | Unused | 0xFFFF FFFFFFFF |

**Table 25: Left Joystick J1939 Extended Joystick Message 1**

### 9.2.3. Right Joystick - J1939 Basic Joystick Message 2 (From VSC)

The joystick message from the SRC includes the 2 primary axes (X, Y) as well as the 4-button D-Pad.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 2 | Right X Joystick Value | See Joystick Reference |
| 2 | 2 | Right Y Joystick Value | See Joystick Reference |
| 4 | 1 | Unused | 0xFF |
| 5 | 1 | Right Button Values | See Button Reference |
| 6 | 1 | Unused | 0xFF |
| 7 | 1 | Unused | 0xFF |

**Table 26: Right Joystick J1939 Basic Joystick Message 2**

### 9.2.4. Right Joystick - J1939 Extended Joystick Message 2 (From VSC)

The joystick message from the SRC includes the third axis (Z).

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 2 | Right Z Joystick Value | See Joystick Reference |
| 2 | 6 | Unused | 0xFFFF FFFFFFFF |

**Table 27: Right Joystick J1939 Extended Joystick Message 2**

### 9.2.5. Heartbeat Message (From VSC)

The heartbeat message from the VSC contains the Emergency Stop indication as well as the current system state.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 1 | VSC Mode | See state definitions |
| 1 | 1 | Autonomy Mode | 0: User Control<br>1: Shared Control<br>2: Autonomous Control |
| 2 | 4 | E-Stop indication | 0 = OK<br>>0 = E-Stop Active<br>(Each bit represents an E-Stop) |

**Table 28: Heartbeat Message (From VSC)**

### 9.2.6. User Feedback Value Message (To VSC)

The User Feedback message to the VSC allows the user to update values that can be displayed on the SRC. Note, even though this message uses a 32-bit into to transmit data, the SRC can only display 6 characters of information (it is capable of displaying all values in the range of a 16-bit integer). Anything out of range will result in a "XXXXXX" to be displayed.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 1 | User Feedback Key | 0-99 |
| 1 | 4 | User Feedback Value | |

**Table 29: Packet Protocol User Feedback Message**

The following keys are currently defined by the system.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. These values should be limited to 16-bit values. |
| 10 | Left Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the left side of the SRC for a small period of time (750ms). |
| 11 | Right Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the right side of the SRC for a small period of time (750ms). |
| 12 | Vibratory Motor Control | Setting this value to 1 will drive both of the vibratory motors of the SRC for a small period of time (750ms). |
| 80 | Inactivity Pause | Controls the time before the SRC goes into Pause Mode because of an Inactivity Timeout. The time before going into Pause Mode is the InactiveTime + 1 in minutes.<br>Valid Values: 0 - 10 |
| 81 | Auto Off Enable | Enables the feature of the SRC to go power-off after 2 minutes past an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 82 | Orientation Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an Orientation Fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 83 | Free-fall Pause Enable | Enables the feature of the SRC to go into Pause Mode because of a Free-fall fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 81 | Inactivity Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 99 | Display Mode | 0 = Default Display Mode<br>1 = User Text Display Mode (4 Lines)<br>2 = User Key Value / Text Display Mode (4 Values w/ Text)<br>3 = User Key Display Mode (8 Values) |

**Table 30: User Feedback Keys**

### 9.2.7. User Feedback String Message (To VSC)

The User Feedback String message to the VSC allows the user to update the displayed name of the user feedback fields. The feedback string is built using 3 segments of 6 characters to build an 18-character string. The full string is combined on the VSC and sent to SRC once the third segment is sent.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 1 | User Feedback Key | 0-99 |
| 1 | 1 | Segment | 0-2 |
| 2 | 6 | User Feedback String | 6 ASCII Characters |

**Table 31: Packet Protocol User Feedback Message**

The following keys are currently defined by the system for user strings.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. Each value has a corresponding text string name. |
| 90 | Custom Display Text Line 1 | In display mode 1, this is the first line of custom text that is displayed. |
| 91 | Custom Display Text Line 2 | In display mode 1, this is the second line of custom text that is displayed. |
| 92 | Custom Display Text Line 3 | In display mode 1, this is the third line of custom text that is displayed. |
| 93 | Custom Display Text Line 4 | In display mode 1, this is the fourth line of custom text that is displayed. |

**Table 32: User Feedback String Keys**

### 9.3. Joystick Reference

The SRC is a 6-axis controller with three on each hand. The X axis and Y axis are mapped to the thumb stick on top of the SRC, while the Z axis is mapped to the finger stick underneath.


**Figure 12: SRC Joystick Axis Reference**

| Byte | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Byte** | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 0 | Axis Magnitude LSB's | | Positive Status | | Negative Status | | Neutral Status | |
| 1 | Axis Magnitude MSB's | | | | | | | |

**Table 33: Packet Protocol Joystick Reference**

| Status | Definition |
|---|---|
| 0x00 | Not Set |
| 0x01 | Set |
| 0x10 | Error |
| 0x11 | Unavailable |

**Table 34: Packet Protocol Joystick Status Reference**

### 9.4. Button Reference

The Buttons on the SRC are configured in a diamond. The buttons are referenced as those shown below on the left hand side of the controller: Up, Down, Left, Right.

**Figure 13: SRC Joystick Button Reference**

| Byte | Bits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Byte** | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| 0 | Left Status | | Up Status | | Right Status | | Down Status | |

**Table 35: SRC Joystick Button Reference**

| Status | Definition |
|---|---|
| 0x00 | Not Set |
| 0x01 | Set |
| 0x10 | Error |
| 0x11 | Unavailable |

**Table 36: SRC Joystick Button Status Reference**

# 10. Interfacing using USB HID Device Protocol

When using the HID Game Controller Protocol, the device is implemented as a standard USB Human Interface Device. On most operating systems it will show up as a standard Game Controller device and can be used the same as any off-the-shelf USB game controller including a Logitech or XBOX Controller.

## 10.1. Packet Structure

The SRCS uses the standard HID device data bytes to transfer information about the measured status of the X, Y and Z-axis of a joystick, and the state of buttons. The SRCS uses custom raw data bytes to transfer the heartbeat and key-value pair information.

## 10.2. Message Types

| Type | Description | Direction | Frequency |
|---|---|---|---|
| Input Report | Standard Message describing sticks and buttons | From SRC | ~16 Hz |
| Output Report | Custom Message containing input control of SRC | To SRC | Aperiodic (Max rate 10 Hz) |

**Table 37: Message Types**

### 10.2.1. Input Report (From SRC)

The Input Report message from the SRC includes the 6 primary axes (Left X, Left Y, Left Z, Right X, Right Y, Right Z), 4-button Directional-Pad, the 4 numbered buttons, the state of the SRC, and the status of the E-STOP. HID class devices are encouraged, where possible, to use a right-handed coordinate system. If a user is facing a device, report values should increase as controls are moved from left to right (X), from far to near (Y) and from high to low (Z).

| Byte Offset | Size (bits) | Description | Value |
|---|---|---|---|
| 0 | 8 | Left X Joystick Value | Increasing left to right from -127 to 127 |
| 1 | 8 | Left Y Joystick Value | Increasing far to near from -127 to 127 |
| 2 | 8 | Left Z Joystick Value | Increasing high to low from -127 to 127 |
| 3 | 8 | Right X Joystick Value | Increasing left to right from -127 to 127 |
| 4 | 8 | Right Y Joystick Value | Increasing far to near from -127 to 127 |
| 5 | 8 | Right Z Joystick Value | Increasing high to low from -127 to 127 |
| 6.0 | 4 | Directional-Pad | Increasing clockwise from Up (0-7)<br>0 = Up<br>2 = Right<br>4 = Down<br>6 = Left<br>8 = Not set |
| 6.4 | 4 | Numbered Buttons | Bit 1 = Button 1<br>Bit 2 = Button 2<br>Bit 3 = Button 3<br>Bit 4 = Button 4 |
| 7 | 1 | SRC State | As described in Table 1 |
| 8 | 1 | E-Stop Value | 0 = Not Actuated<br>1 = Actuated |

**Table 38: Input Report from SRC**

### 10.2.2. Output Report (To SRC)

The Output Report packet to the SRC allows the user to update values that can be displayed on the SRC. Note, even though this message uses a 32-bit into to transmit data, the SRC can only display 6 characters of information (it is capable of displaying all values in the range of a 16-bit integer). Anything out of range will result in a "XXXXXX" to be displayed. The User Feedback message to the SRC allows the user to update the displayed name of the user feedback fields. This message should be sent once during system initialization to set string values for keys, or can be used to continuously update the display.

| Byte Offset | Size | Description | Value |
|---|---|---|---|
| 0 | 1 | User Feedback Key | 0-99 |
| 1 | 4 | User Feedback Value | 32-bit value |
| 5 | 1 | User Feedback String Key | 0-99 |
| 6 | 20 | User Feedback String Value | Up to 20 characters to be displayed |

**Table 39: Packet Protocol User Feedback Message**

The following keys are currently defined by the system for key/value pairs.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. These values should be limited to 16-bit values. |
| 10 | Left Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the left side of the SRC for a small period of time (750ms). |
| 11 | Right Vibratory Motor Control | Setting this value to 1 will drive the vibratory motor on the right side of the SRC for a small period of time (750ms). |
| 12 | Vibratory Motor Control | Setting this value to 1 will drive both of the vibratory motors of the SRC for a small period of time (750ms). |
| 80 | Inactivity Pause | Controls the time before the SRC goes into Pause Mode because of an Inactivity Timeout. The time before going into Pause Mode is the InactiveTime + 1 in minutes.<br>Valid Values: 0 - 10 |
| 81 | Auto Off Enable | Enables the feature of the SRC to go power-off after 2 minutes past an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 82 | Orientation Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an Orientation Fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 83 | Free-fall Pause Enable | Enables the feature of the SRC to go into Pause Mode because of a Free-fall fault detected.<br>0 = Disabled<br>1 = Enabled (default) |
| 81 | Inactivity Pause Enable | Enables the feature of the SRC to go into Pause Mode because of an inactivity timeout.<br>0 = Disabled<br>1 = Enabled (default) |
| 99 | Display Mode | 0 = Default Display Mode |

| | | |
|---|---|---|
| | | 1 = User Text Display Mode (4 Lines)<br>2 = User Key Value / Text Display Mode (4 Values w/ Text)<br>3 = User Key Display Mode (8 Values) |

**Table 40: User Feedback Keys**

The following keys are currently defined by the system for user strings.

| Key | Name | Description |
|---|---|---|
| 1– 9 | User Values | These 9 keys are allocated to custom user values that can be displayed on the LCD screen. Each value has a corresponding text string name. |
| 90 | Custom Display Text Line 1 | In display mode 1, this is the first line of custom text that is displayed. |
| 91 | Custom Display Text Line 2 | In display mode 1, this is the second line of custom text that is displayed. |
| 92 | Custom Display Text Line 3 | In display mode 1, this is the third line of custom text that is displayed. |
| 93 | Custom Display Text Line 4 | In display mode 1, this is the fourth line of custom text that is displayed. |

**Table 41: User Feedback String Keys**

**Troubleshooting**

Here is a list of the most common problems users are reporting, with a solution.

| Issue | Symptom | Solution |
| --- | --- | --- |
| Not receiving data from the VSC. | If the color of the LED is ORANGE, this means that the VSC was reset with the bootloader indicator set. | Verify the state of the Emergency Stop input on the VSC. This is used to tell the VSC to go into bootloader mode on boot. |
| | | |

## 11. Limited Warranty

All products sold by Humanistic Robotics, Inc are subject to the warranty provisions of the Humanistic Robotics Order Confirmation terms and conditions and are warranted against defects in material and workmanship for a period of one (1) year from the date of shipment. If you believe any Humanistic Robotics, Inc product you have purchased has a defect in material or workmanship or has failed during normal use within the warranty period, please contact Humanistic Robotics, Inc for assistance. If product repair or replacement is necessary, the Customer will be solely responsible for all shipping charges, freight, insurance and proper packaging to prevent breakage in transit, whether or not the product is covered by this warranty.

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## 12. Revision History

| Version | Date | Changes |
|---|---|---|
| -01 | 4/10/14 | Initial Release |
| -02 | 5/10/14 | Updates for HID device documentation |
| -03 | 7/10/14 | Updates to HRI packet protocol based on VSC SW version 4.10 |
| | | |

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