Safe Remote Control System

Hardware Manual

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

FORT'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 FORT'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 range of 1000+ ft.
  - Frequency bands include 900 MHz, 2.4 GHz (Other bands available)
- Direct USB interface for easy integration into existing systems
  - Support for USB HID and FORT proprietary interface
- Six fully proportional analog control axes using hall effect, non-contact controls for rugged and reliable performance
- Low-latency control response
- 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 Lithium-Ion battery life for continuous use
- Independent pause (graceful stop) and emergency stop (immediate stop) modes
- Flexible USB charging interface

- Real-time status display as well as extensive system information display in menu
- RP-SMA antenna connector
- IP65 rated enclosure
- Designed to meet MIL-STD-810 for ruggedness
- -20°C to 60°C operation
- Dual lanyard attachments for flexible harnessing options

3. 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.

3.1. 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 SRC will be put into Pause mode 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).

3.2. 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.

3.3. 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.

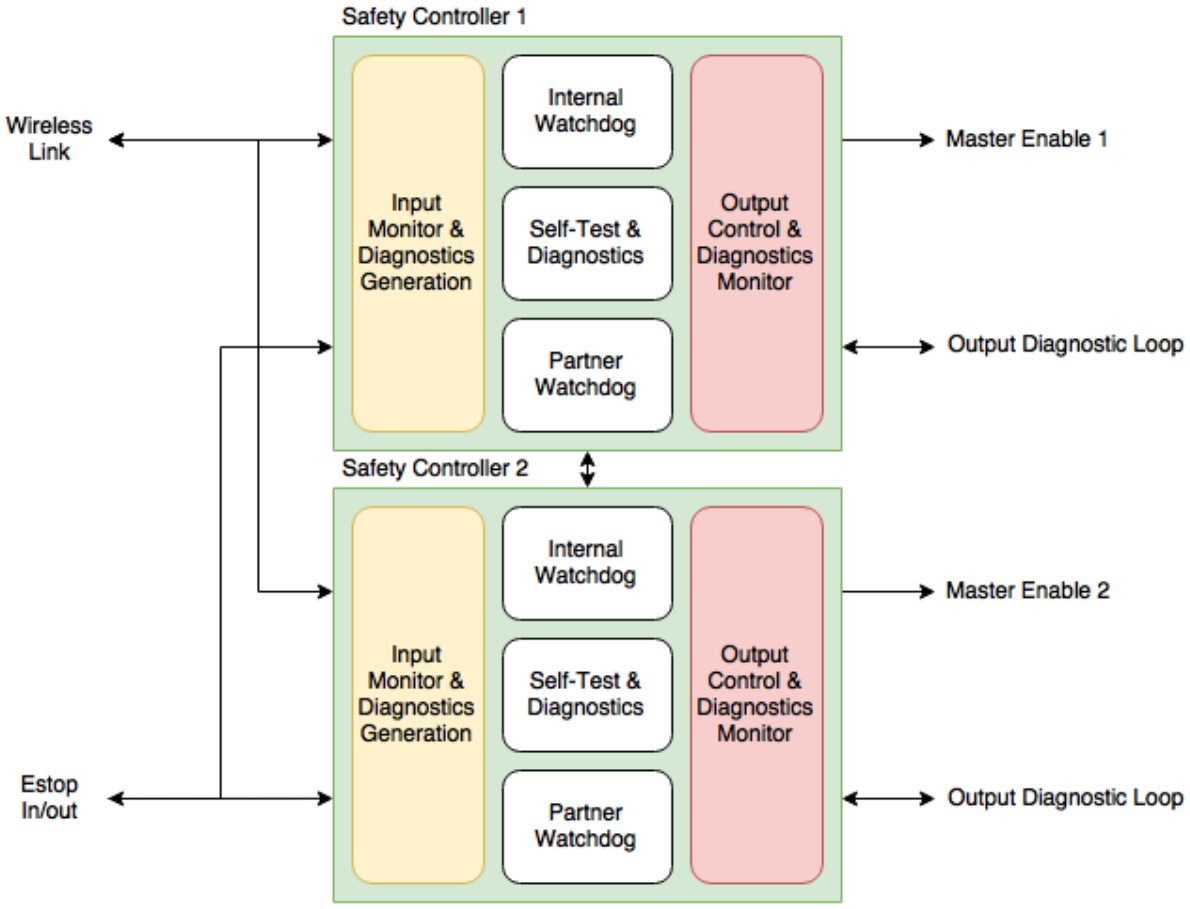

Figure 1 - Internal Hardware Monitors

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.

3.4. 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 385ms (absolute worst case, based on user configuration). This, along with wired emergency stop buttons, gives the system designer significant flexibility.

3.5. Specifications

Parameter	Minimum	Typical	Maximum	Unit
Operating Temperature	-20		+60	°C
Charging Voltage	4.5	5	5.5	V
Charging Current			2.0	A
Battery Life		12		Hours
Ingress Protection	IP67			
Ruggedness	Designed to meet MIL-STD-810			
Weight		587		g
Radio Connector		RP-SMA		
Charging/Programming Connector		Sealed Mini USB with dust plug		
RF Transmit Power[1] (900MHz)			1	W
RF Transmit Power[1] (2.4GHz)			500	mW
RF Receive Sensitivity	-101			dBm
RF Spread Spectrum		FHSS		

Table 1 - Safe Remote Control Specifications

Notes:
1 – Transmit power limited by local regulatory requirements. Maximum for use in EU is 100 mW. Please enquire for details.

4. Typical Integration Methods

4.1. 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 2.

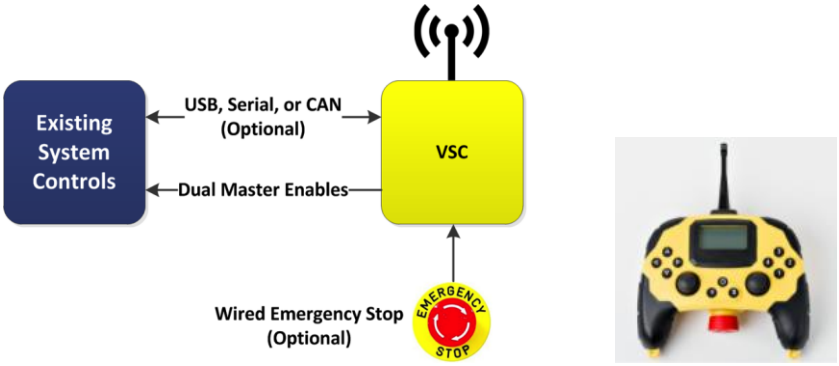

Figure 2 - Simple Receiver Integration

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.

4.2. 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 FORT Packet Protocol as described in the SRCS User 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 FORT 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 FORT Packet Protocol to communicate with the SRCS over a serial device.

5. 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: Local, Remote, Operational, Menu, and Pause. The basic features of these modes are summarized in the table below. 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.

Mode	Value (hex)	Heartbeat	Joysticks	Buttons
Local	0x04	Nominal / E-Stop Indicated	Zeroed	Zeroed
Remote	0x06	Nominal	Zeroed	Zeroed
Operational	0x09	Nominal	Active	Active
Menu	0x0A	Nominal	Zeroed	Zeroed
Pause	0x0B	Nominal	Zeroed	Zeroed

Table 2: SRCS Modes of Operation

5.1. Local Mode

Local 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.

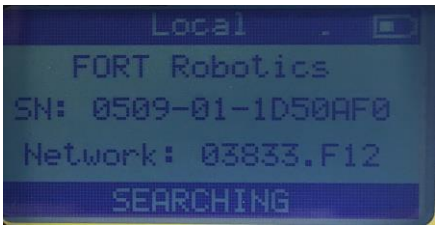

Figure 3: Local Mode

If the VSC is in Local 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, or because the Estop button was pressed. 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.

5.2. Remote Mode

Remote mode occurs when the SRC and the VSC first establish a connection. When in Remote 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 until the user is ready. The VSC's Master Enable relay output from the VSC is energized providing a closed-circuit condition indicating a safe state. The SRC display will look similar to the following in Local Mode.

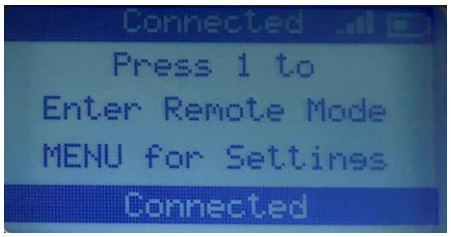

Figure 4: Remote Mode

5.3. Pause Mode

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.

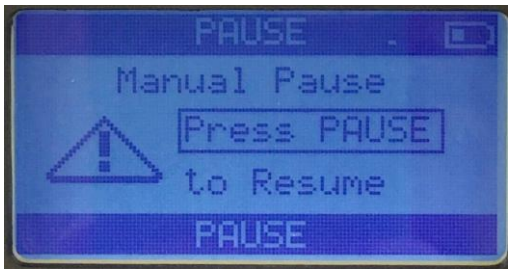

Figure 5: Pause Mode

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's Master Enable relay is energized providing a closed-circuit condition indicating a safe state. The VSC will also continue to output the joystick message with all values set to 0 to guarantee no motion will occur.

5.4. 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. The VSC's Master Enable relay is energized providing a closed-circuit condition indicating a safe state.

Pressing the Menu Button on the SRC is the only way to enter Menu Mode. The SRC display will look similar to the following in Menu Mode.

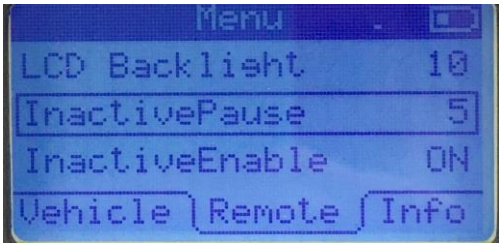

Figure 6: Menu Mode

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

Table 3: Menu Options

5.5. 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. The VSC's Master Enable relay is energized providing a closed-circuit condition indicating a safe state.

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.

5.6. Master Enables

The Master Enable output relays are open-circuit 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.

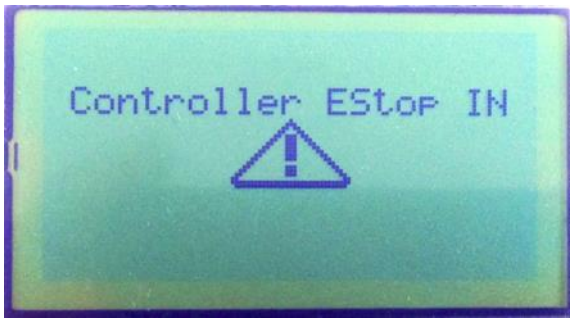

Figure 7: Emergency Stop Display

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.

5.7. 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
Blinking 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

Table 4: VSC LED States

6. Interfacing using FORT Packet Protocol (USB / RS232)

The command and control communication to the VSC is over the RS232 and USB->Serial interface in the FORT 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 FORT 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 FORT 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.

6.1. Data Types

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

Table 5: Packet Protocol Data Types

6.2. 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 6: Packet Protocol Structure

6.3. Message Types

The FORT 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 7: Packet Protocol Message Types

6.3.1. 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 8: Packet Protocol Joystick Message

6.3.2. 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 9: Packet Protocol Heartbeat Message (From VSC)

6.3.3. 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 1: Shared Control 2: Autonomous Control
6	uint32	4	E-Stop indication	0 = OK >0 = E-Stop Active (Each bit represents an E-Stop)
10	uint16	2	16-Bit Checksum	See Checksum Reference

Table 10: Packet Protocol Heartbeat Message (From VSC)

6.3.4. 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) 1 = Medium Strength 2 = High Strength
7	uint8	1	Connection Strength (as perceived by SRC)	Reserved for future use, currently mirrors connection strength as perceived by VSC
8	uint8	1	Reserved	Reserved for future use
9	uint8	1	Reserved	Reserved for future use
10	uint16	2	16-Bit Checksum	See Checksum Reference

Table 11: Packet Protocol Heartbeat Message (From VSC)

6.3.5. 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). **This message is reliant on the Application Layer and is therefore not safety rated.**

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 >0 = E-Stop Active
5	uint16	2	16-Bit Checksum	See Checksum Reference

Table 12: Packet Protocol Heartbeat Message (To VSC)

6.3.6. 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 2: Packet Protocol Heartbeat Message (To VSC)

6.3.7. 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 14: 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. 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. 0 = Disabled 1 = Enabled (default)
82	Orientation Pause Enable	Enables the feature of the SRC to go into Pause Mode because of an Orientation Fault detected. 0 = Disabled 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. 0 = Disabled 1 = Enabled (default)
84	Inactivity Pause Enable	Enables the feature of the SRC to go into Pause Mode because of an inactivity timeout. 0 = Disabled 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) 0 = Disabled (default) 1 = Enabled
99	Display Mode	0 = Default Display Mode 1 = User Text Display Mode (4 Lines) 2 = User Key Value / Text Display Mode (4 Values w/ Text) 3 = User Key Display Mode (8 Values)

Table 35: User Feedback Keys

6.3.8. 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 46: Packet Protocol User Feedback Message

6.3.9. 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 57: 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 68: User Feedback Keys

6.3.10. 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 79: 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 20: User Feedback String Keys

6.4. 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 8: 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 28: Packet Protocol Joystick Reference

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

Table 22: Packet Protocol Joystick Status Reference

6.5. 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 9: 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 93: SRC Joystick Button Reference

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

Table 104: SRC Joystick Button Status Reference

6.6. 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.

```
1.    uint16_t checksum16( uint8_t* data, int count )
2.    {
3.      uint16_t sum1 = 0;
4.      uint16_t sum2 = 0;
5.      int index;
6.
7.      for( index = 0; index < count; ++index )
8.      {
9.        sum1 = (sum1 + data[index]) & 255;
10.       sum2 = (sum2 + sum1) & 255;
11.     }
12.
13.     return (sum2 << 8) | sum1;
14.   }
```

Figure 10: Checksum Reference

7. Interfacing using CAN-J1939 Protocol

The CAN Protocol is a binary protocol whose output is designed to be compatible with the J1939 specification. It is used for all communications between the user and the VSC. This section details the message structure that will be coming from the VSC and required by the VSC to communicate properly. Please note that it does not support address claiming.

7.1. 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.

7.2. 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 E861	Remote Status - J1939 Custom Message	From VSC	1 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 115: Message Types

7.2.1. 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 126: Left Joystick J1939 Basic Joystick Message 1

7.2.2. 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 137: Left Joystick J1939 Extended Joystick Message 1

7.2.3. 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 148: Right Joystick J1939 Basic Joystick Message 2

7.2.4. 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 159: Right Joystick J1939 Extended Joystick Message 2

7.2.5. 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 1: Shared Control 2: Autonomous Control
2	4	E-Stop indication	0 = OK >0 = E-Stop Active (Each bit represents an E-Stop)

Table 30: Heartbeat Message (From VSC)

7.2.6. 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	Size	Description	Value
0	1	Battery Level	Percentage of battery remaining in 10% increments (0-100%)
1	1	Battery Charging	0 = Not Charging, 1 = Charging
2	1	Connection Strength (as perceived by VSC)	0 = Low Connection Strength (intermittent messages, could be disconnected) 1 = Medium Strength 2 = High Strength
3	1	Connection Strength (as perceived by SRC)	Reserved for future use, currently mirrors connection strength as perceived by VSC
4	1	Reserved	Reserved for future use
5	1	Reserved	Reserved for future use
6	2	Reserved	Always 00

Table 31: Remote Status J1939 Custom Message (From VSC)

7.2.7. 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 162: 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. 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. 0 = Disabled 1 = Enabled (default)

82	Orientation Pause Enable	Enables the feature of the SRC to go into Pause Mode because of an Orientation Fault detected. 0 = Disabled 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. 0 = Disabled 1 = Enabled (default)
81	Inactivity Pause Enable	Enables the feature of the SRC to go into Pause Mode because of an inactivity timeout. 0 = Disabled 1 = Enabled (default)
99	Display Mode	0 = Default Display Mode 1 = User Text Display Mode (4 Lines) 2 = User Key Value / Text Display Mode (4 Values w/ Text) 3 = User Key Display Mode (8 Values)

Table 173: User Feedback Keys

7.2.8. 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 184: 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 195: User Feedback String Keys

7.3. 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 11: 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 206: Packet Protocol Joystick Reference

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

Table 217: Packet Protocol Joystick Status Reference

7.4. 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 12: 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 228: SRC Joystick Button Reference

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

Table 239: SRC Joystick Button Status Reference

8. 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.

8.1. 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.

8.2. Message Types

Type	Description	Direction	Frequency
Input Report	Standard Message describing sticks and buttons	From SRC	~16 Hz

Table 40: Message Types

8.2.1. 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) 0 = Up 2 = Right 4 = Down 6 = Left 8 = Not set
6.4	4	Numbered Buttons	Bit 1 = Button 1 Bit 2 = Button 2 Bit 3 = Button 3 Bit 4 = Button 4
7	1	SRC State	As described in Table 1
8	1	E-Stop Value	0 = Not Actuated 1 = Actuated

Table 41: Input Report from SRC

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.
Device is not charging properly	Battery status indicates low charge while on the charger.	Use a USB charger that is rated for at least 2A to charge your device.

10. Limited Warranty

The End-User Agreement can be viewed here at https://fortrobotics.com/end-user-agreement/

The OEM Supply and License Agreement can be viewed here at https://fortrobotics.com/oem-agreement/

11. Revision History

Version	Date	Changes
A	3/1/2021	Initial Release
B	8/19/2021	Added Remote Status Message to CAN interface

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Safe Remote Control Addendum

April 2023

FCC

Caution: Changes or modifications not expressly approved by *the party responsible for compliance* could void the user's authority to operate the equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note:

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

RF Exposure Information

This portable device complies with FCC RF exposure limits for general population/uncontrolled exposure. To ensure compliance, only use an authorized antenna type listed in this manual with this product. Use of an antenna type other than those specified may result in RF exposure levels exceeding the FCC requirements for RF exposure.

ISED

This radio transmitter [IC: 29381-1000350] has been approved by Innovation, Science and Economic Development Canada to operate with the antenna types listed below, with the maximum permissible gain indicated. Antenna types not included in this list that have a gain greater than the maximum gain indicated for any type listed are strictly prohibited for use with this device.

Le présent émetteur radio [IC: 29381-1000350] a été approuvé par Innovation, Sciences et Développement économique Canada pour fonctionner avec les types d'antenne énumérés ci dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué pour tout type figurant sur la liste, sont strictement interdits pour l'exploitation de l'émetteur

Antenna type(s) which can be used with the transmitter

Manufacturer	Antenna Type	Model	Gain (dBi)	Impedance (Ω)
Linx Technologies Inc	¼ Wave Whip, Straight Antenna	ANT-868-CW-QW	1.6	50

This device contains license-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's license-exempt RSS(s). Operation is subject to the following two conditions:

1. This device may not cause interference.
2. This device must accept any interference, including interference that may cause undesired operation of the device.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

1. L'appareil ne doit pas produire de brouillage;
2. L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

RF Exposure Requirements

This portable device complies with ISED RF exposure limits for general population/uncontrolled exposure. To ensure compliance, only use an authorized antenna type listed in this manual with this product. Use of an antenna type other than those specified may result in RF exposure levels exceeding the ISED requirements for RF exposure.