

USER MANUAL

VAMPIRE

DATA RECORDER AND ANOMALY DETECTION

PART NUMBER:
NW-1553-ML-VA01



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1 VAMPIRE OVERVIEW

The purpose of Vampire is to capture MIL-STD-1553 bus traffic. It performs this function in 2 ways: streaming the bus content to an internal SD card for post processing of the data and sending the decoded data out of the device over the Ethernet connection.

The Vampire hardware, shown in Figure 1, decodes the bus controller (BC) / remote terminal (RT) interaction and transmits the information over the Ethernet connection. For efficiency, one Ethernet packet is transmitted from Vampire for every eight MIL-STD-1553 BC/RT interactions. Vampire also creates high precision timestamps for the BC and RT traffic. Each bus BC message has a timestamp resolution of 5 nanoseconds (ns) which is 4x the industry standard. The RT response also has a resolution of 5 ns which is 20x the industry standard. To protect the avionics busses, Vampire performs as a one-way device. Vampire is not capable of transmitting MIL-STD-1553 packets and is unable to receive Ethernet data.

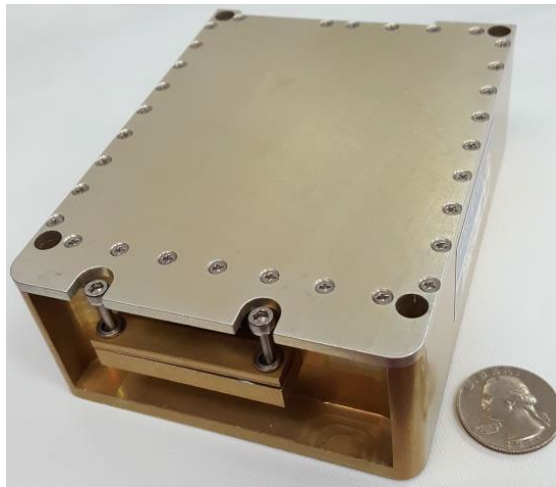


Figure 1: Vampire offers a ruggedized design in a favorable package size.

2 SETTING UP VAMPIRE

2.1 INTERFACE DEFINITIONS

The connector pin-out definitions for the module's connector are provided in Table 1. In a typical installation, the Vampire module is mated to a MIL-STD-1553 data bus and power supply via an interface cable.

Table 1: Vampire Pin-Out Definitions

Pin Number	Pin Name	I/O	Description
1	+28 VDC	I	DC Supply Voltage, +28 Volts.
2	28 VDC Ret	I	DC Supply Voltage Return
3	USB D-	I/O	USB Data (Negative)
4	USB D+	I/O	USB Data (Positive)
5	USB VCC	I	USB Voltage
6, 8, 16, 19, 21, 23, 24, 25, 27, 29	GND	I	DC Ground.
7	BI_DD-	I/O	Ethernet, Bidirectional Data Bus D (Negative)
9	BI_DD+	I/O	Ethernet, Bidirectional Data Bus D (Positive)
10	BI_DC-	I/O	Ethernet, Bidirectional Data Bus C (Negative)
11	BI_DC+	I/O	Ethernet, Bidirectional Data Bus C (Positive)
12	BI_DA+	I/O	Ethernet, Bidirectional Data Bus A (Positive)
13	BI_DA-	I/O	Ethernet, Bidirectional Data Bus A (Negative)
14	BI_DB-	I/O	Ethernet, Bidirectional Data Bus B (Negative)
15	BI_DB+	I/O	Ethernet, Bidirectional Data Bus B (Positive)
17	CH1_H	I/O	MIL-STD 1553 Channel 1 (Positive)
18	CH1_L	I/O	MIL-STD 1553 Channel 1 (Negative)
20	CH2_L	I/O	MIL-STD 1553 Channel 2 (Negative)
22	CH2_H	I/O	MIL-STD 1553 Channel 2 (Positive)
26	CH3_L	I/O	MIL-STD 1553 Channel 3 (Negative)
28	CH3_H	I/O	MIL-STD 1553 Channel 3 (Positive)
30	CH4_L	I/O	MIL-STD 1553 Channel 4 (Negative)
31	CH4_H	I/O	MIL-STD 1553 Channel 4 (Positive)

2.2 INTERFACE CABLE (PURCHASE OPTION)

The 36" shielded interface cable is comprised of a micro-D connector on one end, with four MIL-STD-1553 connectors, one power connector, ethernet, and USB-A for interfacing with the user's implementation. This cable provides input power to the Vampire module and allows interfacing with the MIL-STD-1553 data bus. Figure 2 shows NuWaves part number CYB-CBL-01-F.

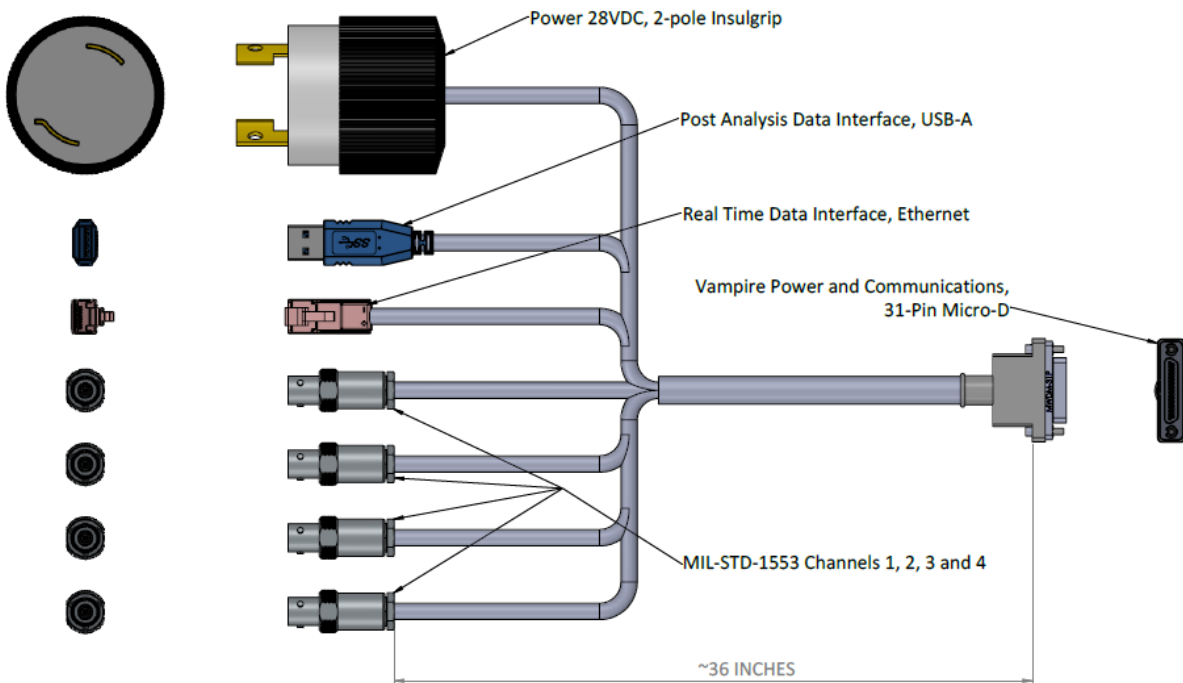


Figure 2: CYB-CBL-01-F Vampire Interface Cable

2.3 POWER CONNECTION

The nominal operating voltage of Vampire is 28V DC, but it is capable of handling 10V to 36V DC. The power is supplied to the device through the miniature sub-d connector. The current draw of Vampire is approximately 300 mA, but is dependent on the number of busses being connected to the device and the traffic loading on the busses.

2.4 MIL-STD-1553 BUS CONNECTIONS

Figure 3 illustrates how Vampire can be connected to four MIL-STD-1553 channels. The four channels may be any combination of an “A” or “B” bus. The bus traffic on all four channels is decoded and sent out of the module over the Ethernet connection. However, only the traffic on CH1 and CH2 is written to the SD card.

The MIL-STD-1553 connections on the end of the Vampire interface cable are Trompeter CJ70-29.

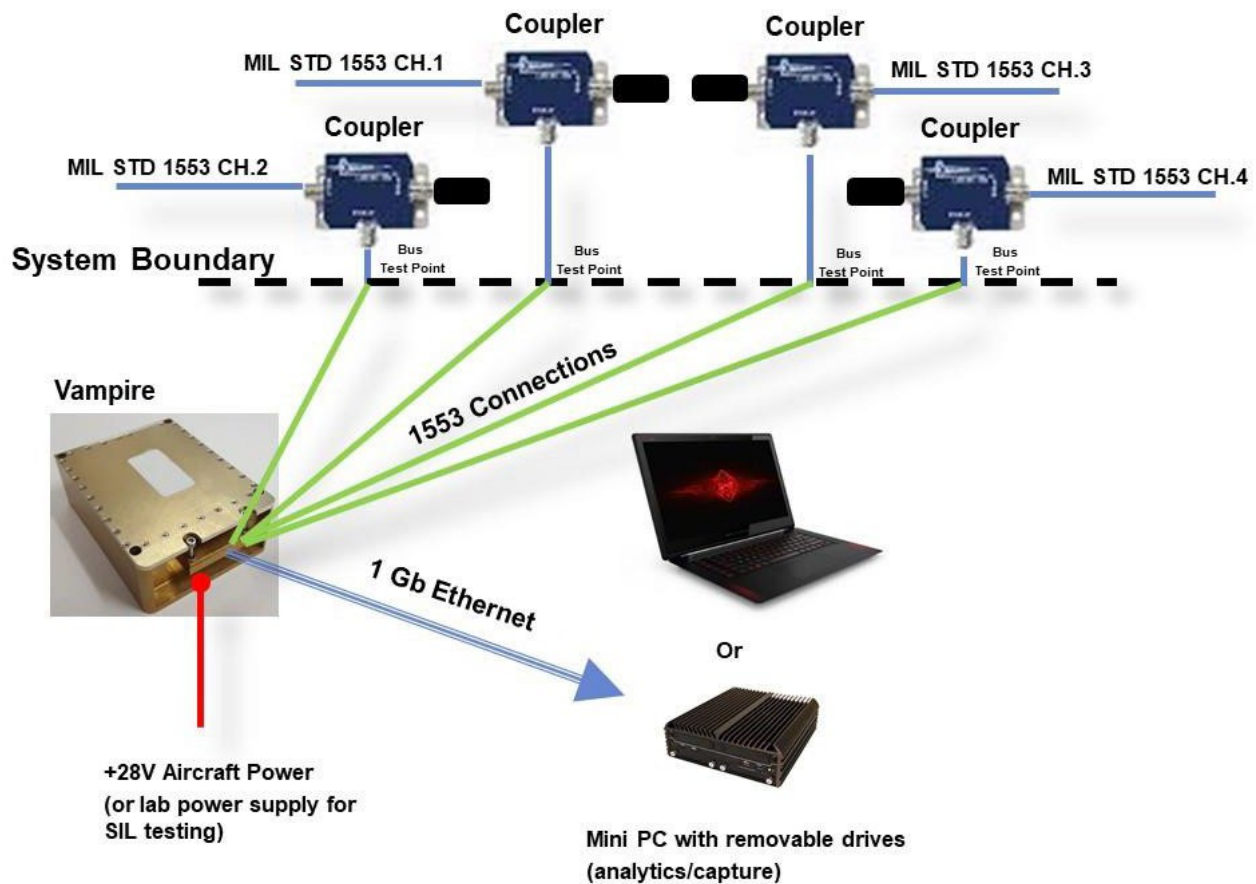


Figure 3: Example implementation of Vampire to four MIL-STD-1553 channels

2.5 LED CONFIGURATION

Vampire has 5 tri-color light emitting diodes (LED) internal to the module as seen in Figure 4. These LEDs can be viewed by removing the back cover of the module. After the module has completed its power-on sequence, D30 will turn green. D29 turns red once the SD Card is done collecting data. D28 flashes blue as the SD Card is collecting data. D32 and D31 turn red when there is traffic on CH1 or CH4 and turn purple when there is traffic and the SD Card is present.

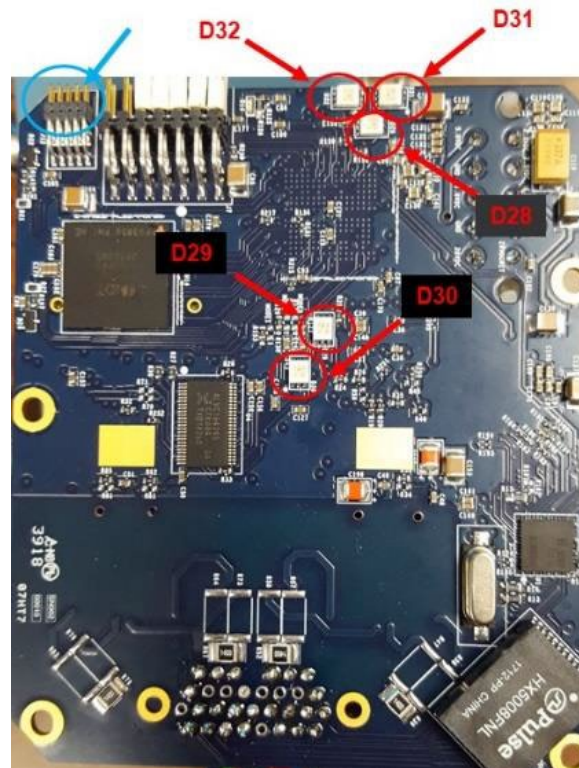


Figure 4: Board level indicators and configuration jumpers

2.6 SETTING THE RECORDING TIME

Vampire has a dual row of 0.05 pins which are used to set the SD Card's recording time with a jumper. These pins are circled in blue in Figure 4. The pair of pins furthest from the edge of the card have the shortest record time and the pins closest to the edge have the longest record time. The record times are 2 minutes, 30 minutes, 4 hours, and 10 hours. If no jumper is used, the record time is set to the maximum.

2.7 ETHERNET

Once powered on and Vampire sees MIL-STD-1553 traffic, the Ethernet port automatically sends out broadcast packets. The packets are UDP packets sent from IP address 169.254.115.183. The packets can be captured for post processing using Wireshark software on a PC, or they can be captured and analyzed in real time with software such as RYWA's Cyber-physical Intrusion Detection Software (CIDS). The format of the UDP packets can be seen in the appendix, Table 2.

The Ethernet connection on the end of the Vampire interface cable is an L-Com TRD815SPL-7.

2.8 SD CARD DATA CAPTURE

Vampire uses MIL-STD-1553 bus transceivers to convert each MIL-STD-1553 channel into two digital signals. This is a standard MIL-STD-1553 architecture. Vampire captures both digital signals from each of the two channels at 10 MHz and continuously records the data to the SD Card. The length of time to be recorded is dependent on the jumper setting mentioned in section 2.4.

The SD Card can be a standard size SD memory card, or a micro SD card (as long as it is in a standard size SD card carrier). **The memory card also needs to be a minimum of class 10 and type XC.** Busses are sampled at a rate of 10 MHz in the FPGA. As such, a 256 Gb card will hold approximately 10 hours of recorded data.

Vampire can log the MIL-STD-1553 traffic without being connected via Ethernet to a computer. To log a MIL-STD-1553 bus, the SD Card can be inserted at any time. The FPGA goes through an ~18 second initialization with the SD card, checks the lock switch on the card, and then begins to log data.

Note the data on the SD card will be over written if the lock switch is not properly set on the SD card.

A blinking LED inside the module confirms data is being logged. The LED will continue to blink until the configured record length has been reached. Once the record time has been reached the LED will become solid.

3 DATA ANALYSIS

This section provides an overview of the AFRL/Rywa software tools available for analyzing the data captured by Vampire either on the SD Card or over the Ethernet output. It is not meant to be a complete user guide for the tools. Because the Ethernet output is not proprietary, it makes Vampire a great front-end tool for other researchers to develop their own analysis system using Vampire's output.

3.1 POST FORENSICS ANALYSIS OF CAPTURED DATA FROM VAMPIRE'S ETHERNET OUTPUT

AFRL/Rywa has created a software program named Day-Walker (see Figure 5) for performing post forensics analysis of the captured Ethernet traffic from Vampire. By opening the pcap file saved by Wireshark, Day-Walker can: generate a report of the bus traffic (see example in Appendix A.4), show the frequency of the RTs being called by the BC, show the available sub addresses of the RTs, plot the response times of the RTs, plot individual word values over time and convert the pcap file to a comma delimited file.

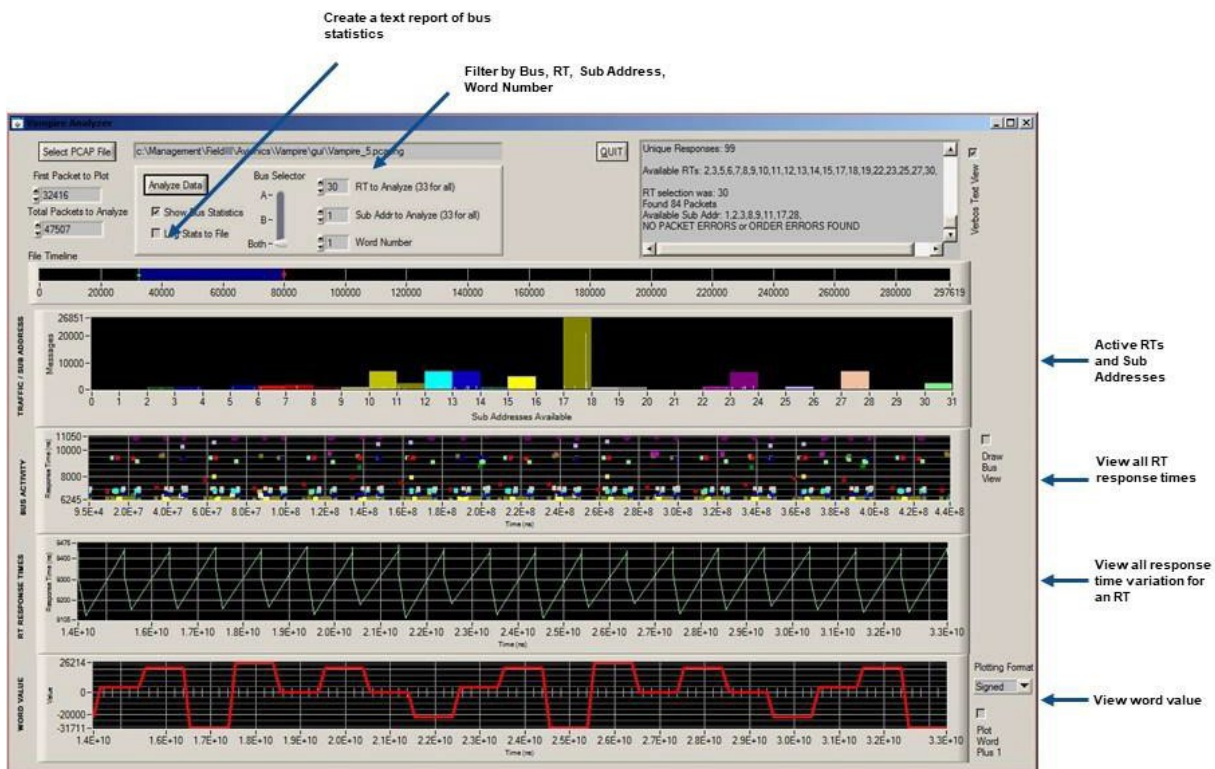


Figure 5: Post forensics data analysis using Day-Walker

3.2 REAL-TIME BUS ANALYSIS USING VAMPIRE

AFRL has created a software program called CIDS which parses the incoming UDP packets for visualization and anomaly detection. The software has several levels of analysis which can be performed on the real-time Ethernet data. Several screens are shown below.

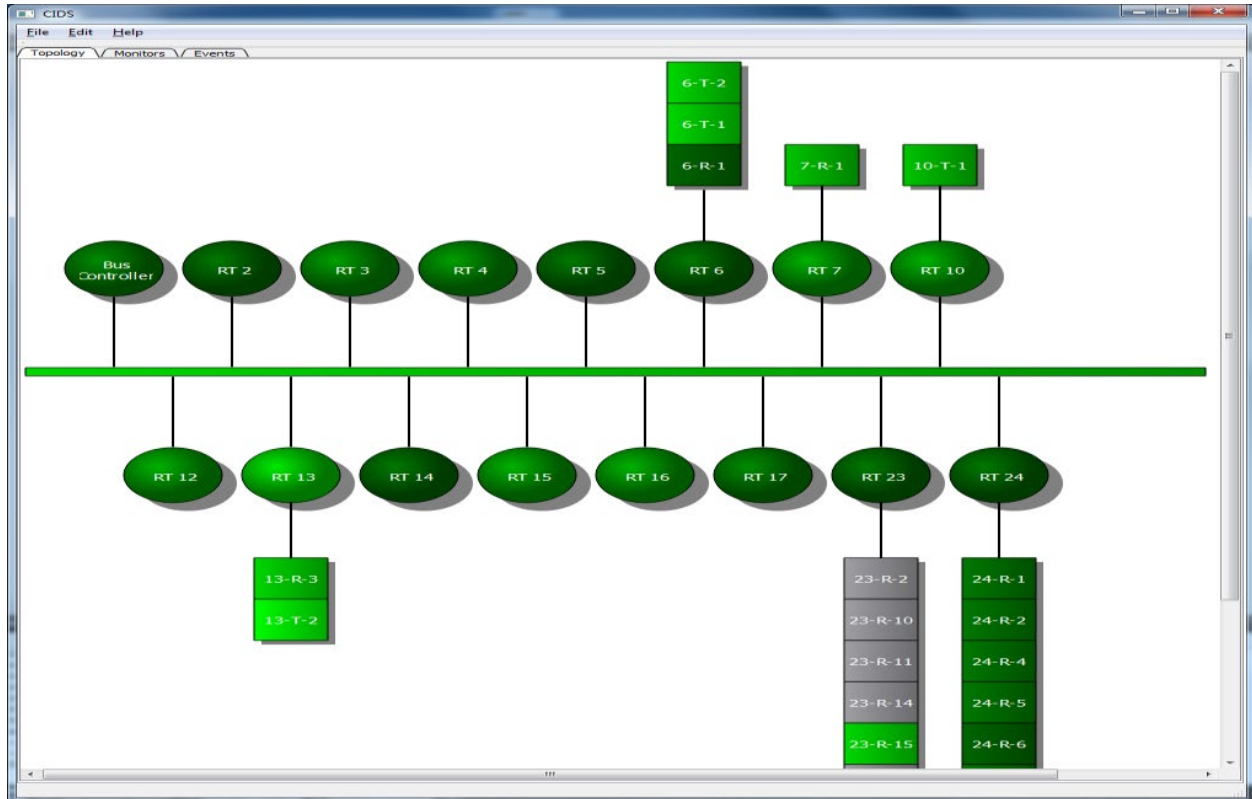


Figure 6: Visualizing the MIL-STD-1553 bus in real time with CIDS

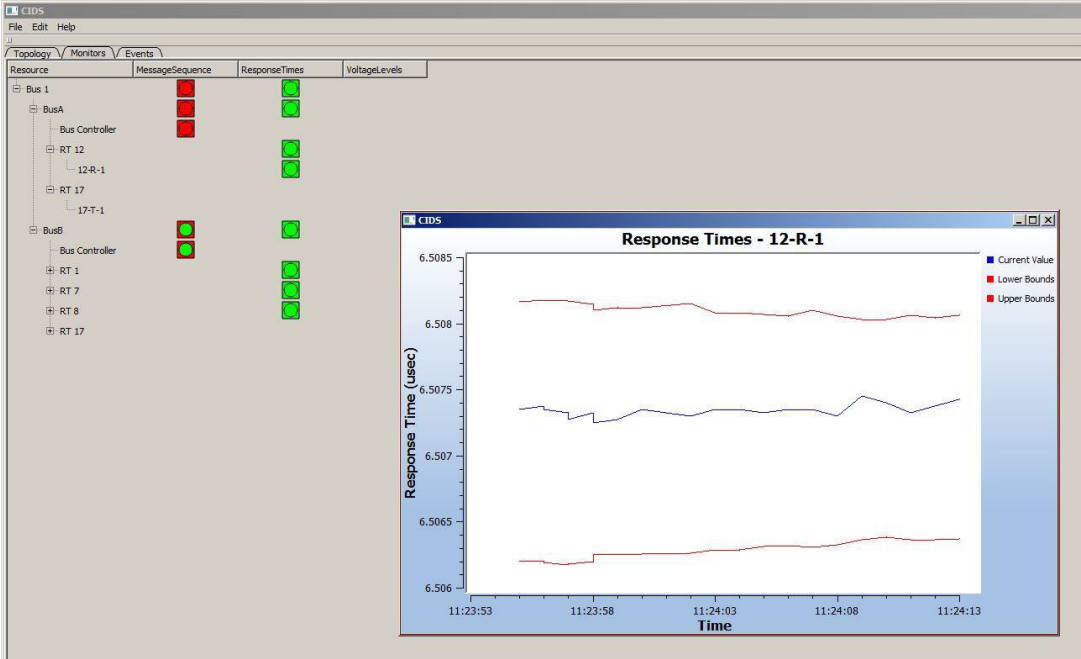


Figure 7: Anomaly detection using RT response times with CIDS



Time	Type	Affected Resource(s)	
11:24:57	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:24:57	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:25:15	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:25:15	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:25:15	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.
11:25:15	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.
11:25:18	ResponseTimes	1-R-1	The response times for message '1-R-1' of RT 'RT 1' has shown a normal, repeatable rate.
11:25:18	ResponseTimes	7-T-1	The response times for message '7-T-1' of RT 'RT 7' has shown a normal, repeatable rate.
11:25:18	ResponseTimes	8-T-0	The response times for message '8-T-0' of RT 'RT 8' has shown a normal, repeatable rate.
11:25:18	ResponseTimes	12-R-1	The response times for message '12-R-1' of RT 'RT 12' has shown a normal, repeatable rate.
11:26:06	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:26:06	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:26:21	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:26:21	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:26:22	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.
11:26:22	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.
11:27:08	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:27:08	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a change.
11:27:12	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:27:12	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has started to show a repeatable pattern.
11:27:12	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.
11:27:12	MessageSequence	Bus Controller	The message sequence on bus 'Bus 1' has shown a repeatable pattern for an extended period of time.

Figure 8: Bus errors as tracked by CIDS.

3.3 ANALYSIS OF DATA CAPTURED ON THE SD CARD

The data on the SD Card can be analyzed with AFRL/RYWA's Sandstorm software. Sandstorm helps the end user to visually inspect the MIL-STD-1553 bus. Because the raw traffic is recorded to the SD Card instead of decoded traffic, problems on the bus can be analyzed in-depth. Figure 9 shows a screen capture Sandstorm.

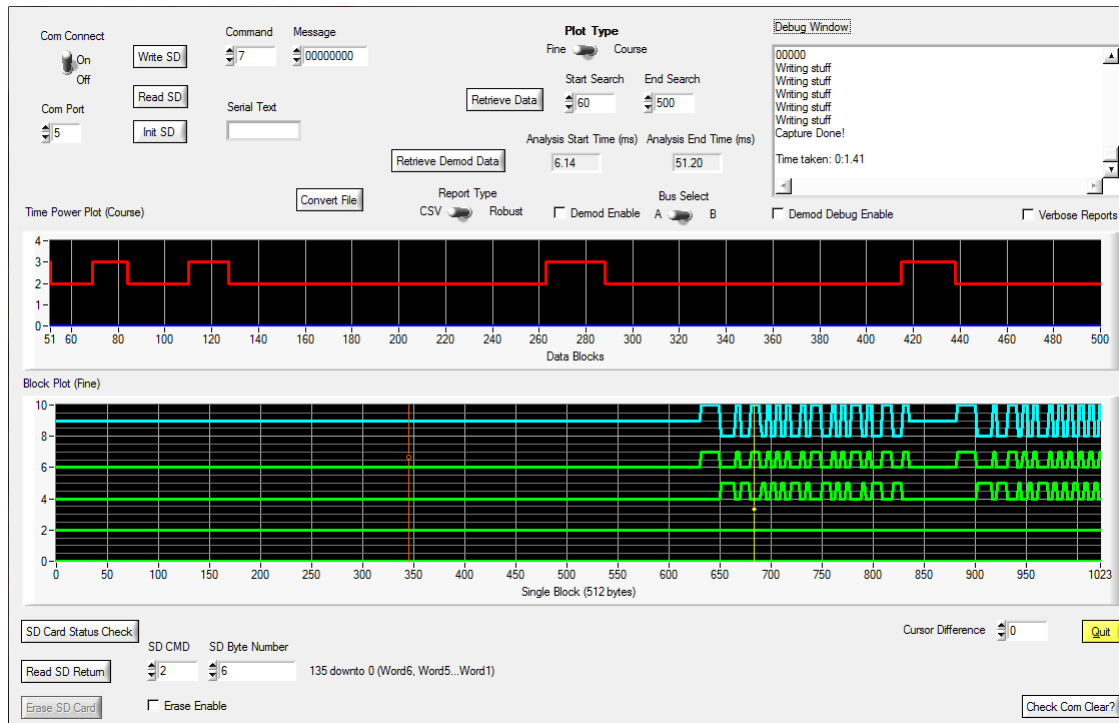


Figure 9: Bit transitions captured and graphed by Sandstorm

4 MECHANICAL

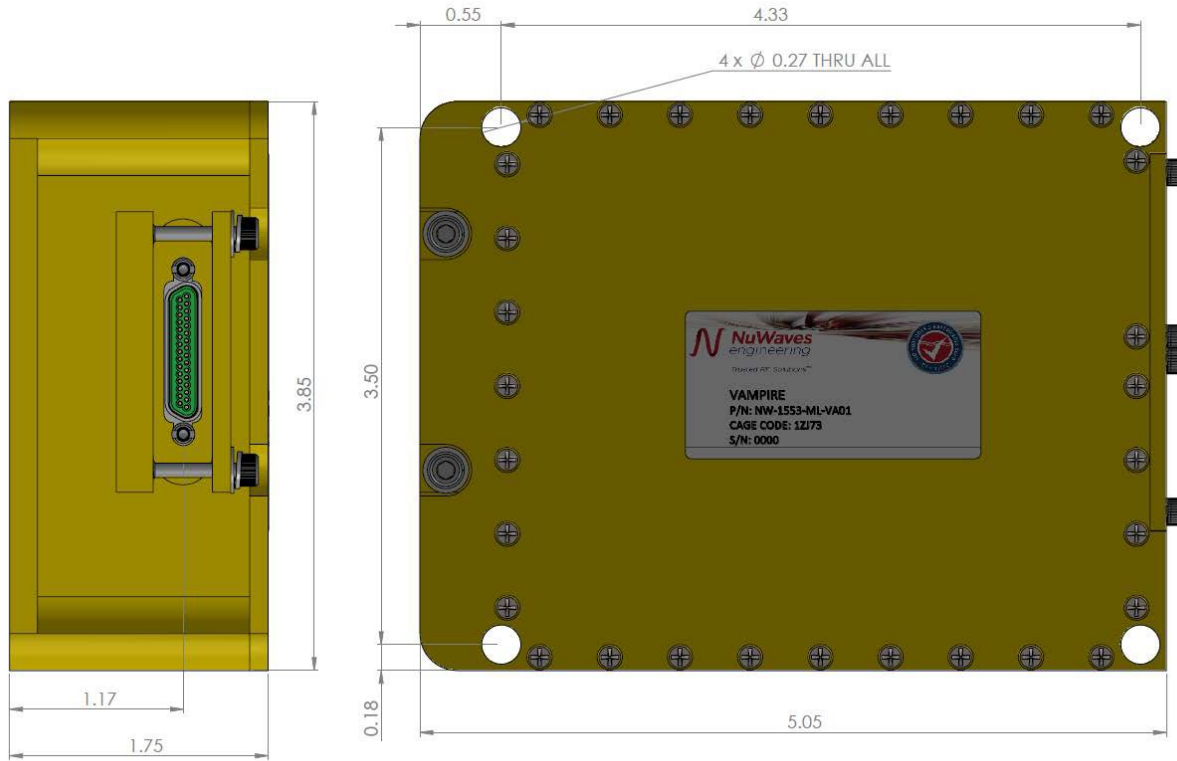


Figure 10: Vampire Mechanical Outline

Table 2: Vampire Mechanical Specifications

Parameter	Specification
Interface Connector	31 Pin Micro-D
Dimensions (LxWxH)	5.05" x 3.85" x 1.75"
Weight	2.0 lbs

5 TROUBLESHOOTING

Common questions and answers to troubleshooting Vampire.

Q: Why am I not seeing any Ethernet traffic using CIDS?

A: Ethernet traffic is only available if there is MIL-STD-1553 traffic. Verify there is traffic on the bus by checking the 2 LEDs behind the back cover. If the LEDs are not red or purple, there is no traffic or the wrong MIL-STD-1553 connector could be plugged into the stub coupler.

Q: Why am I not seeing any Ethernet traffic on my computer and the LEDs are on?

A: Make sure the firewall on the computer is off. If using Wireshark, make sure it is in promiscuous mode. Additionally, the Ethernet connection is 1Gb. If the Ethernet is plugged into a switch, the switch must support 1Gb.

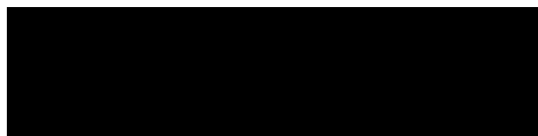
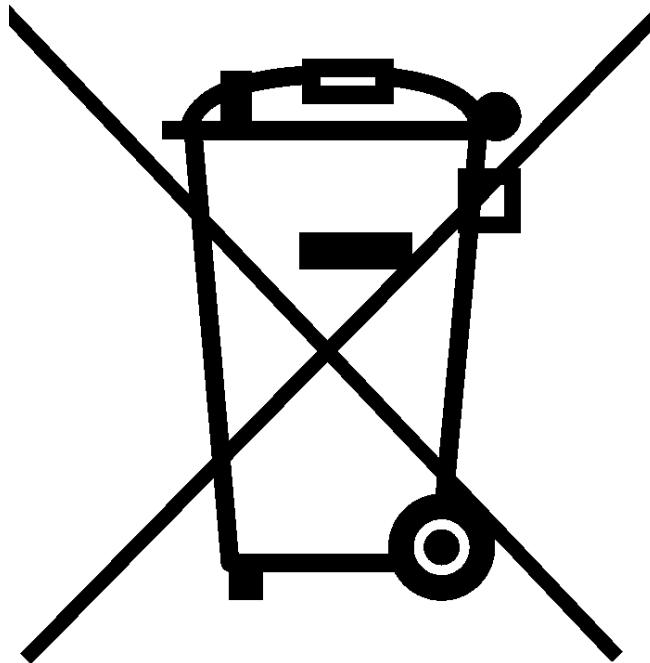
Q: Why can't I connect to Vampire over the serial port using the SD Analyzer GUI?

A: Make sure the correct COM port is being selected in the GUI. You might have to check Windows Device Manager to see which COM port showed up.

6 PRODUCT DISPOSAL – END-OF-LIFE

Safety is a guiding principle of NuWaves RF Solutions. We ensure safe production and operation of our products, as well as end-of-life disposal. Improper disposal can adversely affect the environment, wildlife and human health. Please follow these guidelines when disposing of a NuWaves product:

- Do not remove the cover or any hardware
- Do not remove components from the circuit card assembly
- Do not incinerate
- Do not crush or shred
- Do not dispose of as unsorted municipal waste
- Do not export e-waste outside of the original destination country for recycling
- Utilize an e-Steward or ISO14001 certified e-waste recycler
- Consider export controls during recycler selection
- If a NuWaves product is incorporated into a larger system or sub-system, ensure that these guidelines are followed at system end-of-life



7 GETTING HELP - APPLICATIONS ENGINEERING

NuWaves RF Solutions offers technical support for basic configuration help and troubleshooting, Monday through Friday, 8 a.m. to 5 p.m. Eastern Time.

Technical Assistance and Application Engineering:

Email: sales@nuwaves.com

Phone: (513) 360 - 0800

NuWaves Home Page: <https://www.nuwaves.com/>

Product Warranty:

https://products.nuwaves.com/wp-content/uploads/NuWaves_Warranty_Repair.pdf

7.1 GENERAL INFORMATION

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8 APPENDIX

Table 1: Acronyms

BC	Bus Controller
FPGA	Field Programmable Gate Array
GUI	Graphical user interface
LED	Light emitting diode
RT	Remote Terminal
SD	Secure digital

8.1 REFERENCES

1. Day-Walker User Guide, AFRL/Rywa, 2020.
2. Sandstorm User Guide, AFRL/Rywa, 2020.
3. CIDS User Guide, AFRL/Rywa, 2020.

8.2 SERIAL PORT

The serial port baud rate is 115k baud. Packets are 8 ASCII hex characters in length. Write packets start with a "\$" while read packets start with a "#". Register addresses are 2 ASCII hex characters and the register data is 5. Therefore, a register write to address 1 with data 6 would look like "\$0100006". A read would look like "#0100000". (The quotes are not part of the message.)

All serial packet writes are followed automatically by a return message on the serial port. The response packet is the value of the register after it was written to.

* Errors: 0x0 - No errors, 0x1 - Cmd sync error, 0x2 - Cmd error, 0x3 - Data sync error, 0x4 - Word decode error, 0x5 - Transfer error, 0x6 - Busy, 0x7 - No reply

8.4 EXAMPLE TEST REPORT FROM DAY-WALKER SOFTWARE

*** Some content was removed for consolidation purposes.

Vampire Analysis of Flight Data

File Name: c:\Management\FieldIII\Avionics\Vampire\gui\Vampire_6.pcapng

File Size is: 50001216 bytes

BC / RT interactions (approximate): 288184

**RT: 2, Total Messages = 504 Sub Addresses. Messages = 1.92, Reply Time (Max): 8840, (Min): 8590, (Median): 8671

2.114, Reply Time (Max): 8905, (Min): 8815, (Median): 8823

14.23, Reply Time (Max): 8585, (Min): 8560, (Median): 8565

15.115, Reply Time (Max): 8730, (Min): 8685, (Median): 8604

17.114, Reply Time (Max): 8840, (Min): 8755, (Median): 8769

18.23, Reply Time (Max): 8705, (Min): 8685, (Median): 8685

28.23, Reply Time (Max): 8855, (Min): 8815, (Median): 8828

**RT: 3, Total Messages = 506 Sub Addresses.

Messages = 1.92, Reply Time (Max): 9415, (Min): 9335, (Median): 9344

17.46, Reply Time (Max): 9435, (Min): 9370, (Median): 9387

28.368, Reply Time (Max): 9440, (Min): 9325, (Median): 9277

**RT: 11, Total Messages = 1517 Sub Addresses.

Messages = 1.92, Reply Time (Max): 9760, (Min): 9350, (Median): 9601

2.919, Reply Time (Max): 9605, (Min): 9355, (Median): 9355

3.23, Reply Time (Max): 9600, (Min): 9560, (Median): 9575

8.115, Reply Time (Max): 9480, (Min): 9390, (Median): 9399

9.115, Reply Time (Max): 9440, (Min): 9355, (Median): 9374

11.115, Reply Time (Max): 9440, (Min): 9390, (Median): 9405

17.23, Reply Time (Max): 9710, (Min): 9665, (Median): 9679

28.115, Reply Time (Max): 9600, (Min): 9560, (Median): 9562

**RT: 17, Total Messages = 17737 Sub Addresses.

Messages = 0.23, Reply Time (Max): 6320, (Min): 6270, (Median): 6285

1.920, Reply Time (Max): 6330, (Min): 6250, (Median): 6209

13.919, Reply Time (Max): 6335, (Min): 6250, (Median): 6250

26.14036, Reply Time (Max): 6335, (Min): 6245, (Median): 6249

27.1839, Reply Time (Max): 6330, (Min): 6240, (Median): 6242

Available RTs: 2,3,5,6,7,8,9,10,11,12,13,14,15,17,18,19,22,23,25,27,30,

RT selection was: 33

Found 0 Packets

Available Sub Addr: 0,1,2,3,4,5,7,8,9,11,13,14,15,16,17,18,19,23,24,26,27,28,

NO PACKET ERRORS or ORDER ERRORS FOUND