REPORT

MIL-STD-1553B to ARINC 429 Data Conversion with Commercial Off-the-Shelf (COTS) Equipment

BY DAVID L. GARCIA OF AGILYNX INC.

EDITOR'S NOTE: This report is published by Avionics News *with clearance from the Department of Defense and is for training purposes only. Its sole intent is to improve the maintenance technician's knowledge and understanding of the content provided. Refer to a manufacturer's most current technical data, maintenance and/or installation manuals whenever performing maintenance on aircraft or aircraft components.*

ABSTRACT

The feasibility of converting MIL-STD-1553B databus traffic to ARINC 429 databus transmissions in real time with an airborne quality commercial-off-the-shelf data converter has been demonstrated in a number of applications, including those on C-130, CN-235, H-60, A319 and AT-63 aircraft. In these cases, the built-in flexibility and pre-programmed features of the PCU-100 Lynx Protocol Converter unit produced by AgiLynx Inc. of Billerica, Mass., have allowed an extremely short time between the specification of the data conversion task and the configuration of a unit for flight testing – sometimes in less than a week. This capability allows COTS avionics products to become fully integrated into existing or future military avionics systems.

The Lynx Protocol Converter unit has the ability to monitor all transmissions on a MIL-STD-1553B databus and transfer data to multiple ARINC 429 busses without requiring any programming changes to the existing 1553B system or disturbing existing bus traffic. While not itself a source of data, the Lynx Protocol Converter acts as a "data bridge," extracting copies of data and retransmitting the data to the output busses.

Alternately, the Lynx Protocol Converter unit can also transfer data to a MIL-STD-1553B databus by acting as a remote terminal or a bus controller. The Lynx Converter can receive up to 12 ARINC 429 inputs and transmit on a MIL-STD-1553B dual-redundant bus (a second dual-redundant 1553B bus is bus monitor only at this time), as well as transmitting on four ARINC 429 outputs. ARINC 429 interfaces can be either 12.5 or 100 Kbps.

The Lynx Converter also has six each of open/ground and 28V/open discrete inputs and two each of open/ground and 28V/open discrete outputs. An RS-232 communication port is used to connect to a device, such as a laptop for programming the Lynx Converter unit or using the Lynx Converter for system troubleshooting.

The PCU-100 Lynx Protocol Converter unit is designed as a generic device that can be configured for specific applications using the AgiLynx developed LynxCom-Pro software program. The LynxCom-Pro software runs on a personal computer and allows a user, in a point-and-click fashion, to set up the data conversion for a specific application.

After an application setup is defined, the LynxCom-Pro software is used to permanently download the configuration into a Lynx Protocol Converter unit.

The LynxCom-Pro software can also be used to troubleshoot the unit configuration in the laboratory because of its ability to simulate MIL-STD-1553B or ARINC 429 data inputs and observe the output of the Lynx Protocol Converter unit.

BACKGROUND

When adding COTS equipment to aircraft utilizing a MIL-STD-1553B "1553B" databus, it is often required that data from the 1553B bus be made available in the ARINC 429 "ARINC" databus format. A possible approach is to use a COTS data converter to perform this function. The COTS data converter could act as a 1553B bus monitor, extract parameters such as position or velocity from the 1553B bus, convert the data into the ARINC format, and then transmit the parameters in a timely fashion on one or more ARINC busses.

This conversion task, while on first appearance very straightforward, requires a number of special capabilities (all provided by the Lynx Protocol Converter unit). These capabilities include:

- Handle input rates different from the output rates.
- Change the number of bits, the bit alignment and the bit resolution from input to output.
- Change engineering units from input to output (for example, semi-circles to degrees, feet/second to feet/minute, feet to nautical miles, seconds to hours:minutes:seconds).
- Convert multiple-word input parameters to single-word output parameters.
- Monitor data validity bits for each parameter and set the sign/status matrix for each corresponding ARINC 429 label.
- Suspend transmission of individual ARINC 429 labels if 1553B data is not present for more than a specified number of seconds.

Since it has the built-in functionality to handle the above tasks, the Lynx Converter unit can be quickly configured for an integration effort.

As incoming and outgoing data can be required in many formats, the Lynx Converter unit can transfer data in the following formats:

- Un-signed binary.
- Two's-complement.
- Sign-magnitude.
- Binary coded decimal signed.
- BCD unsigned.
- BCD SSM related (per ARINC 429).
- Floating point.

The floating point formats supported are generic with user selectable formulas, exponents and bias. Some representative formats supported are as follows:

Type	# of Bits	Exp. / Frac.	**Formula** (S = sign, F = fraction, E = exponent)
IEEE _32	32	8 / 23	$((-1)^S)(1.F)(2^{(E-127)})$
IEEE _64	64	11 / 52	$((-1)^S)(1.F)(2^{(E-1023)})$
DEC _32	32	8 / 23	$((-1)^S)(0.1F)(2^{(E-128)})$
DEC _64	64	8 / 55	$((-1)^S)(0.1F)(2^{(E-128)})$
DEC _64G	64	11 / 52	$((-1)^S)(0.1F)(2^{(E-1024)})$
IBM_32	32	7 / 24	$((-1)^S)(0.F)(16^{(E-64)})$
IBM_64	64	7 / 56	$((-1)^S)(0.F)(16^{(E-64)})$
1750A _32	32	8 / 23	$(-1S + 0.F)(2^E)$
1750A _48	48	8 / 39	$(-1S + 0.F)(2^E)$
TI_32	32	8 / 24	$(-3S + 1.F)(2^E)$
TI_40	40	8 / 32	$(-3S + 1.F)(2^E)$

Once integration testing proceeds one may often discover subtleties, such as some required parameters are not available from the same source address on the MIL-STD-1553B databus during the entire flight regime and at a fast enough update rate. For example, parameters might be available from different source addresses, but with the following characteristics:

1. The required input rate of 25 Hz can be acquired from a

Continued on following page

DATA CONVERSION WITH COTS EQUIPMENT

Continued from page 65

triplet of equally spaced MIL-STD-1553B messages received at 8.33 Hz.

2. The triplet of messages can switch to another triplet when the aircraft changes operational modes.

To accommodate these input characteristics, the following features of the Lynx Converter unit could be used:

- Time-stamp indicating the reception time of each incoming parameter.
- Comparator function (used to compare time-stamps to determine the most current input value).
- Conditional transmission of ARINC 429 labels (used to switch on and off the virtual data streams from the separate source addresses).

In one actual case, these features enabled the quick modification of the Lynx Converter over a weekend to time-multiplex the data while rate changing the 25 Hz input rate to a 20 Hz output rate.

The following time related functions are built into the Lynx Converter:

- Time from unit power-up.
- Time-stamp of received word.
- Time since word last received.
- Time from 1553B synchronize point to word last received.
- Number of times word received (freshness counter).

The following comparator related functions are built in to the Lynx Converter:

- Compare input to constant (<, <=, =, >=, >, <>) and set a bit with the result.
- Compare two input values (<, <=, =, >=, >, <>) and set a bit with the result.

The conditional transmission capabilities built into the Lynx Converter are as follows:

- ARINC 429 or 1553B transmissions can be conditional on the state of an input discrete or combinations of input discretes.
- Bus controller operation can be conditional on the state of an input discrete or combinations of input discretes.
- For redundant ARINC 429 input receivers, data output can be switched to the redundant input based on the state of an input or combinations of input discretes.

TYPICAL SYSTEM OVERVIEW

The PCU-100 Lynx Protocol Converter is being used in a number of applications and programs which are currently in different stages of development, ranging from system rig testing, to in-flight testing, to in-production use. The following table lists some of the applications and projects using the Lynx Converter:

Aircraft Type	Project	1553 I/F	429 I/F
C-130	Cockpit upgrade - new FMS, radios, and displays	BM	4 Rx 2 Tx
---	(Confidential)	RT	1 Rx
AT-63	Add engine with Digital Engine Control	BM	2 Tx
A319	Add IFF System	--	1 Rx 1 Tx
CN-235	Add INS to FMS; be BC when Search Radar is off.	BM / BC	1 Tx
H-60	(Confidential)	BM	4 TX
A319	Add IFF system	--	4 Rx / 2 Tx

(BM = 1553B Bus Monitor; RT = 1553B Remote Terminal; BC = 1553B Bus Controller)

The following is a representative example of the use of PCU-100 Lynx Protocol Converter unit, where the unit is connected to an aircraft dual-redundant MIL-STD-1553B ("1553B") databus to acquire aircraft data and generate outputs on four ARINC 429 ("ARINC") databusses for a COTS avionics unit (see Figure 1).

While the PCU-100 Lynx Protocol Converter can interface with a 1553B databus by acting as a bus monitor, remote terminal, or bus controller, or even combinations of these three interfaces, it is configured for this example as a bus monitor, which allows the capture of data from the 1553B bus without disturbing the existing bus operation or requiring any special commands from the existing bus controller. Once connected to a 1553B bus (via a transformer coupler), the Lynx Converter acting as a bus monitor observes all existing bus traffic and captures transmissions in parallel with the equipment normally on the bus.

The COTS avionics expects specific data on four different ARINC inputs; the Lynx Converter meets this requirement by having four independent ARINC outputs, and is able to switch input data from either of two 1553B dual-redundant inputs or up to 12 ARINC inputs to any output.

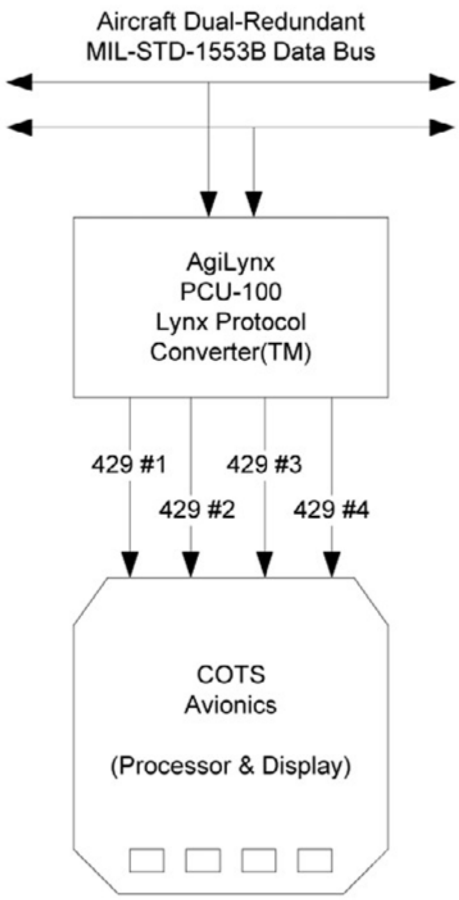

Figure 1 – System Diagram

Trans-mitter	Label	Label Name	Tx Rate
TX1 (High Spd)	320	Magnetic Heading (degrees)	20 Hz
TX2 (High Spd)	203	Uncorrected Altitude (feet)	20 Hz
TX2 (High Spd)	164	Radio Altitude	20 Hz
TX2 (High Spd)	76	GPS Altitude	20 Hz
TX3 (High Spd)	136	Vertical Error (feet)	20 Hz
TX3 (High Spd)	247	Horizontal Error (Nautical Miles)	20 Hz
TX4 (High Spd)	150	Time HH:MM:SS	20 Hz
TX4 (High Spd)	165	GPS Vertical Speed	20 Hz
TX4 (High Spd)	275	LRN Status Word HS Valid (bit 29)	20 Hz
TX4 (High Spd)	310	Present Position Latitude	20 Hz
TX4 (High Spd)	311	Present Position Longitude	20 Hz

Table 1- ARINC 429 Data

The PCU-100 Lynx Protocol Converter is configured for a specific application by using a graphical-user-interface program developed by AgiLynx called LynxCom-Pro. This program runs on a standard personal computer using the Microsoft Windows operating system and allows a user to configure a Lynx Converter in a point-and-click fashion by selecting and specifying the inputs, the outputs and the conversion details needed for a specific application. After using LynxCom-Pro to set up an application, it is used to communicate with and download the configuration into the Lynx Converter. Once the configuration is downloaded, it is permanently stored unless over-written by a new configuration. The Lynx Converter will report the configuration identifying information when requested with a version command.

DATA TRANSFER

ARINC 429 Data: The ARINC data required by the COTS avionics to be extracted from the 1553B bus is shown in Table 1 – ARINC 429 Data:

The four ARINC transmitters of the Lynx Converter are configured to output at the high-speed rate (100 kbaud), and labels are scheduled to transmit at 20 Hz. When data validity associated with each parameter indicate invalid data, the SSM bits are set to "failure warning."

MIL-STD-1533B Data: The MIL-STD-1553B data collected by the Lynx Converter is sourced from two remote terminals: a GPS unit (RT-17) and a video display unit (RT-06). Acting as a bus monitor, the Lynx Converter can collect data from any transmission type on the bus: bus controller to RT, RT to BC, or RT to RT. Data to or from an RT is further identified by sub-address (1-30), and then the word number (0-31). For example, pressure altitude from the GPS is identified as RT17-R10-04; -R10 indicates (receive) sub-address 10, -04 indicates word four. Individual bits

Continued on following page

Continued from page 67

may also be obtained by the Lynx Converter; for example the pressure altitude validity is bit 11 from word three identified as RT17-R10-03-11.

The data from the 1553B bus required by the COTS avionics is shown in Table 2 – MIL-STD-1553B Source Data:

RT Addressing	Word/Bit Name	Rx Rate
RT17-R10-04	Pressure Altitude (feet) Validity: RT17-R10-03-11	25 Hz
RT17-T09-09	GPS Altitude (feet) Validity: RT17-T09-17-03	1 Hz
RT17-T09-19	Est. Vertical Position Error (feet) Validity: RT17-T09-17-03	1 Hz
RT17-T09-21/22	UTC Measurement Time (seconds) Validity: RT17-T09-01-08	1 Hz
RT17-T09-15/16	GPS Velocity Up (feet/second) Validity: RT17-T09-17-03	1 Hz
RT17-T09-18	Est. Horizontal Position Error (feet) Validity: RT17-T09-17-03	1 Hz
RT17-T09-01	Navigation Mode Word Validity: RT17-T09-01- 00 (0 = Not Valid, 1 = Valid)	1 Hz
RT17-T09-5/6	GPS Latitude (semi-circles) Validity: RT17-T09-17-03	1 Hz
RT17-T09-7/8	GPS Longitude (semi-circles) Validity: RT17-T09-17-03	1 Hz
RT06-(R01,R02,R03) or (R04,R05,R06) -05	Compass Heading (semi-circles) Validity: RT06-(R01,R02,R03) or (R04,R05,R06)-05-15	8.3 Hz x 3 = 25 Hz
RT06-(R01,R02,R03) or (R04,R05,R06) -06	Radar Altitude (feet) Validity: RT06-(R01,R02,R03) or (R04,R05,R06)-06-02	8.3 Hz x 3 = 25 Hz

Table 2- MIL-STD-1553B Source Data

The RT Addressing column of Table 2 indicates that some parameters comprise one word and some comprise two words. In the two-word cases, a most significant word is concatenated with a least significant word to evaluate the parameter. Also shown is that the compass heading and radar altitude parameters are received from six different RT06 receive sub-addresses, three at a time (R01, R02, R03) or (R04, R05, R06). The individual update rates are 8.33 Hz each, but they are equally spaced in time from each other and have fresh values to form an aggregate update rate of 25 Hz. The groups of three switch depending on the operating mode of the aircraft.

Data Conversion: The PCU-100 Lynx Protocol Converter is designed as a generic device that can be configured for specific applications using the LynxCom-Pro personal computer software program. The general process to set up data conversion was to define the detailed characteristics of the input and output parameters and then set up the connections between them. LynxCom-Pro provides a hierarchical data tree structure on the left side of the screen, which allows the user to expand input or output objects and specify the associated parameter details (see Figure 2 – LynxCom-Pro Screen).

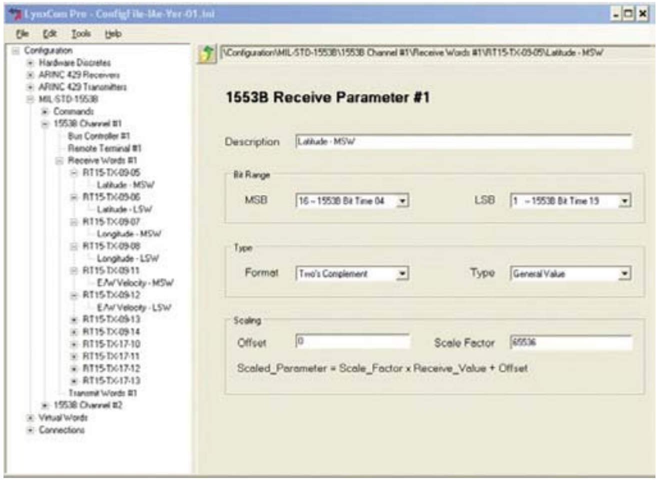

Figure 2 – LynxCom-Pro Screen

Inputs and outputs were set up by naming the associated parameters, specifying the bit alignment within the incoming or outgoing word and specifying the bit resolution (least-significant bit weight) by entering a double-precision floating-point scale factor.

Connections between inputs and outputs were defined by selecting from a set of operators called connectors. The parameter connector simply transfers an input to an output.

If unit conversion is required, a linear transformation is possible by entering a scale factor and offset, both being double-precision floating point values. For this application, the linear conversions included feet to nautical miles, semi-circles to degrees and feet/second to feet/minute.

Data from multiple input words are combined into single parameters using a double-parameter connector, which combines two inputs into a single 32-bit output value and a 32-bit remainder, using double-precision floating-point arithmetic. This same connector is used to convert seconds to hours:minutes:seconds as follows: a first double-parameter connector converts seconds to hours with a fractional hours remainder, a second double-parameter connector then converts the hours remainder to minutes with a fractional minutes remainder, and a final Parameter Connector converts the minutes remainder into the final seconds parameter. These three output parameters are then formatted for the final output of hours:minutes:seconds.

Input discrete bits are processed by connectors to drive output discrete bits, to control operations, or to drive ARINC 429 sign/status matrix bits. A discrete to SSM connector reads data validity bits from the MIL-STD-1553B data and drives the SSM status of "normal operation" or "failure warning," while taking into account the type of ARINC 429 label being transmitted, as the two-bit code for normal operation/failure warning differs among binary, BCD and discrete labels.

Since the desired output rate of ARINC transmissions is often desired to be regular (20 Hz) and may differ from the input rate of the associated input parameter (25 Hz), the Lynx Converter operates in the following fashion. All inputs are immediately stored when received. If a new value is received, it over-writes the old value. ARINC outputs are transmitted per a defined schedule. When a label is due to be transmitted, the current (newest) value in memory is accessed, scaled, formatted and output. This effectively decouples the output rate from the input rate, and the system designer need only determine that the combination of input/output rates meet the required system refresh rate.

When the ARINC output labels are configured, an option is presented to define a time-out value, such that if the 1553B data destined for an ARINC output label is not received for more than a specified interval, then the label transmission will be terminated until fresh data is received.

In this example, the compass heading (Label 320) and radar altitude (Label 164) parameters are not available on the 1553B bus from a fixed remote terminal address, and are acquired as follows:

- The required input rate of 25 Hz must be acquired from a triplet of equally spaced 1553B messages received at 8.33 Hz.
- The triplet of messages switches to another triplet when the aircraft changes operating mode.

To accommodate these input characteristics, the Lynx Converter is configured as follows:

Connect each 1553B sub-address to transmit on the appropriate ARINC label.

- Use a comparator connector in conjunction with time-stamps to determine the most current input value.
- Use the output of the comparator connector to control the conditional transmission of the ARINC 429 labels, so that only the most current value will be transmitted.

TESTING

In some cases it is desirable to perform a separate integration test between the Lynx Converter and a COTS avionics unit prior to testing both items in the target end system.

To achieve this integration test without benefit of the 1553B bus traffic present on the target system, a bench-test configuration of the Lynx Converter unit can be generated that exploits the ability of the Lynx Converter unit to act simultaneously as a bus monitor, remote terminal and bus controller.

This capability allows the Lynx Converter unit, acting as both a bus controller and a remote terminal, to simulate a portion of the target system 1553B databus traffic, and then simultaneously act as the bus monitor to collect data from that simulated traffic and drive the ARINC output data to the COTS avionics unit.

Another function of the LynxCom-Pro personal computer application that can be used during integration testing is the LynxMonitor function, which allows the user to set and/or observe values that the Lynx Converter unit is inputting and outputting.

With the LynxMonitor function, an integration team can set various values and verify that they are received properly by the COTS avionics and the interpretation of the scaling and resolution is correct.

This capability has allowed the quick resolution of interface issues among connected systems using the Lynx Converter unit.

CONCLUSION

The successful integration of avionics into aircraft using the PCU-100 Lynx Protocol Converter unit demonstrates that a COTS approach to MIL-STD-1553B to ARINC 429 data conversion is feasible in a military aircraft avionics architecture.

The powerful feature set built into the Lynx Protocol Converter unit accommodates a wide variety of real-world situations and allows the integration of COTS avionics without time-consuming software changes and reverification efforts.

The Lynx Protocol Converter unit is designed as a generic avionics device that meets aircraft standards (DO-160D and DO-178B), yet is quickly configurable for a wide variety of applications, using the LynxCom-Pro software application on a personal computer. ❑