Team AI - 26

AVIONICS INTEGRATION TEST BENCH DESIGN

ELEC 491 Capstone Project

University of British Columbia

11 April 2023

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Glossary

Term	Definition
ARINC	Aeronautical Radio Inc. (Communication Protocol)
CDC	Communication Device Class (for USB)
DMA	Direct Memory Access
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FIFO	First In First Out
FPGA	Field Programmable Gate Array
GPIO	General Purpose Input Output
GUI	Graphical User Interface
I/O	Input/Output
IC	Integrated Circuit
LSB	Least Significant Bit
MCU	Microcontroller
MSB	Most Significant Bit
OS	Operating System
PCB	Printed Circuit Board
RX	Receive
SPI	Serial Peripheral Interface
TX	Transmit
USB	Universal Serial Bus
VCP	Virtual COM Port

1. Project Context

1.1 Background Information

The *Avionics Integration Test Bench* is designed to emulate bi-directional communication of various aircraft parameters between avionics equipment in testing that is awaiting installation on an aircraft, and existing avionics on an aircraft (FR1). The test bench allows a user to control the values of flight data parameters transmitted on ARINC 429 data buses to equipment under test (EUT), and also facilitates interpretation of values received from the EUT (FR1.1). ARINC 429 (often referred to as simply "ARINC" here) is a technical standard for digital communication of data between avionics systems on commercial aircraft. As the integration of avionics equipment into aircraft is a time consuming and expensive process, this test bench will allow avionics engineers at the project client company, KF Aerospace, to decrease their risk of discovering integration issues while modifying an aircraft. It will also facilitate experimentation with novel integration techniques.

The motivation, context and specifications for the design of this test bench are described thoroughly in the project requirements document. Specifications in the requirements document are referenced here according to the conventions described therein; in short, specifications are denoted "FRx", "NFRx", and "Cx".

The *Avionics Integration Test Bench*, titled AeroSim, is a USB-to-ARINC 429 interface device (FR2) accompanied by a GUI PC software program (FR3). The device features 6 output buses (from computer to EUT; FR2.1.1) and 8 input buses (from EUT to computer; FR2.1.2) that interface with ARINC 429-compatible avionics equipment. The interface device also provides several avionics-style discrete electrical outputs of both GND/open-circuit and 28V/open-circuit varieties. The software runs on a Windows OS computer (C6) and allows a user (an avionics engineer) to control flight parameter data sent to avionics equipment while simultaneously interpreting data received from avionics equipment, and control the discrete outputs. The desired flight parameter values to be sent are entered into the GUI, and received parameter values are

displayed and logged in a text file. A depiction of the expected test bench setup is presented in Figure 1.1.

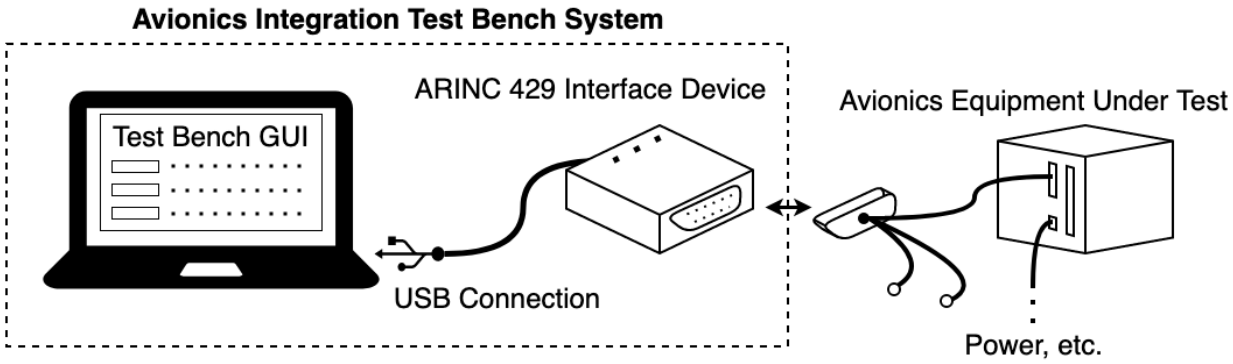


Figure 1.1 - Depiction of the expected Avionics Integration Test Bench system setup with equipment under test.

1.2 Summary of ARINC 429

Many elements of the *Avionics Integration Test Bench*'s design are dictated by the ARINC 429 standard [1]. Although all the utilised specifications from the standard cannot be collected here, a summary of ARINC 429 is presented in Appendix A in order to contextualise many design decisions and features prescribed with respect to the standard.

Appendix A: ARINC 429 Summary

ARINC 429 digital communication is described and depicted in the following 3 sections each at a different level of abstraction: at the bus level, at the word content level, and at the bit encoding level.

Digital information is transferred on a given ARINC 429 bus in a single direction from 1 transmitting device to 1-20 receiving devices. Electrically, a bus is a single differential pair. A single piece of avionics equipment generally has interfaces for multiple buses to transmit data on and multiple buses to receive data on. Data is sent in chunks called “words.” Many words contain a single flight data parameter, such as an altitude measurement, or a GPS-determined latitude, but many formats for data within a word exist [3].

A.1 Bus Level

One field required in all words is a numeric label that identifies the content of the word. Labels are assigned meanings by the standard. For example, one type of altitude measurement, “pressure altitude,” is label 203 (in octal base). The standard gives several specifications for data transfer by individual label, including a fixed time interval at which that label’s data should be transmitted. Any combination of different labels can be transmitted on one bus. Figure A.1 depicts an example sequence of transmitted words over time.

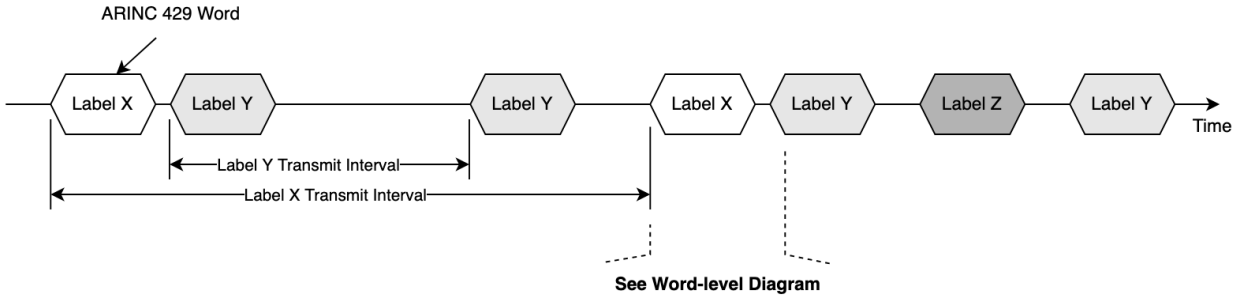


Figure A.1 - An example sequence of transmitted words on an ARINC 429 Bus over time.

A.2 Word Level

All ARINC 429 words are 32 bits long. The format of information within those 32 bits is generally specified by the standard to encourage compatibility between equipment. The label and parity fields are always required. The format of the rest of the message depends on the label, but most labels follow the partial format specification shown in Figure A.2. Figure A.2 also shows an arbitrary example word as encoded on the ARINC 429 bus.

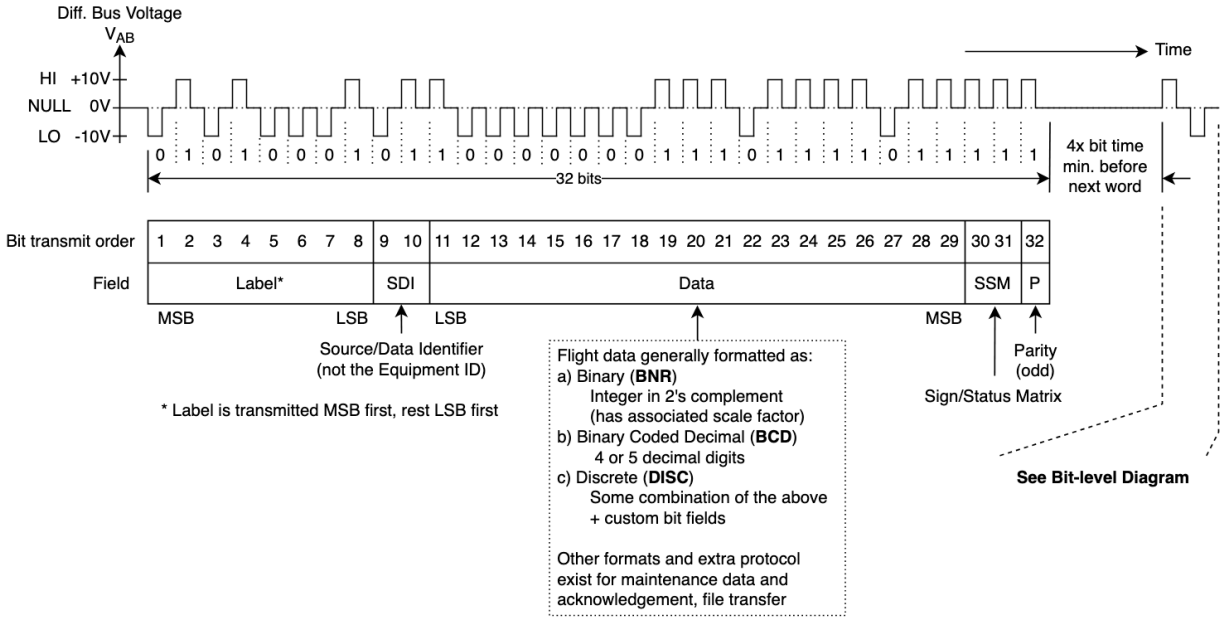


Figure A.2 - ARINC 429 word format and arbitrary example bus encoding.

A.3 Bit Level

Abbreviated specifications from the ARINC 429 standard for the bit encoding and timing used on the differential pair of an ARINC 429 bus are depicted in Figure A.3. Voltages V_A and V_B are the respective voltages of the 2 lines A and B in the differential pair with respect to the electrical ground, which is shared by all avionics equipment connected together.

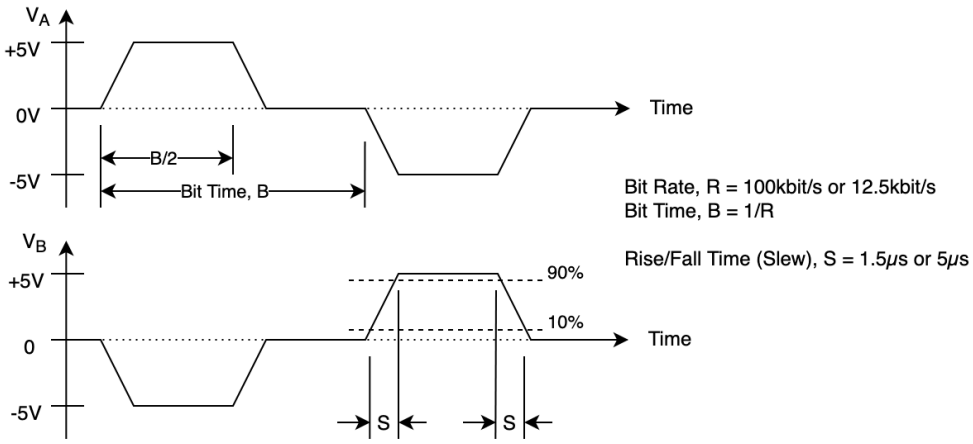
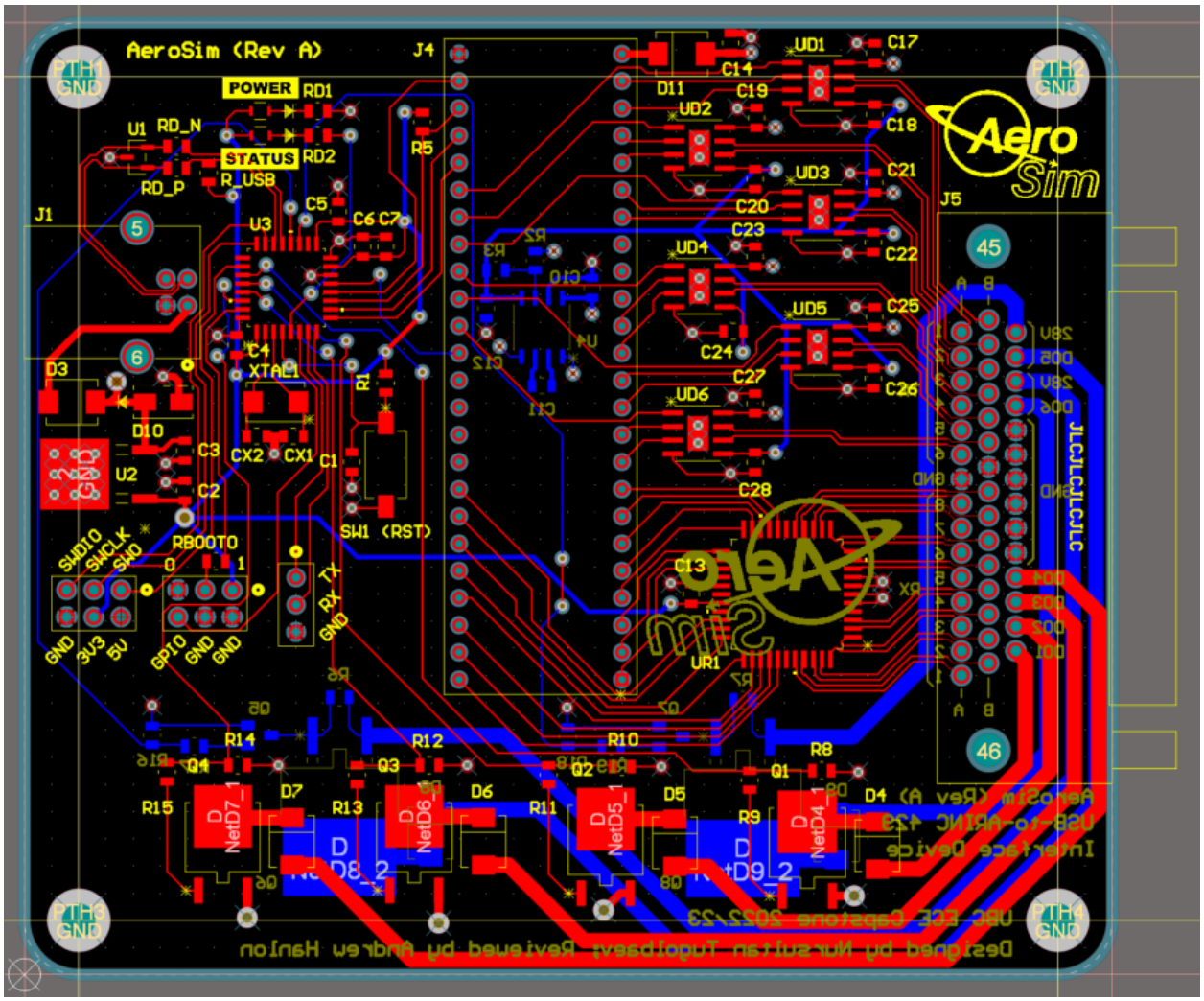
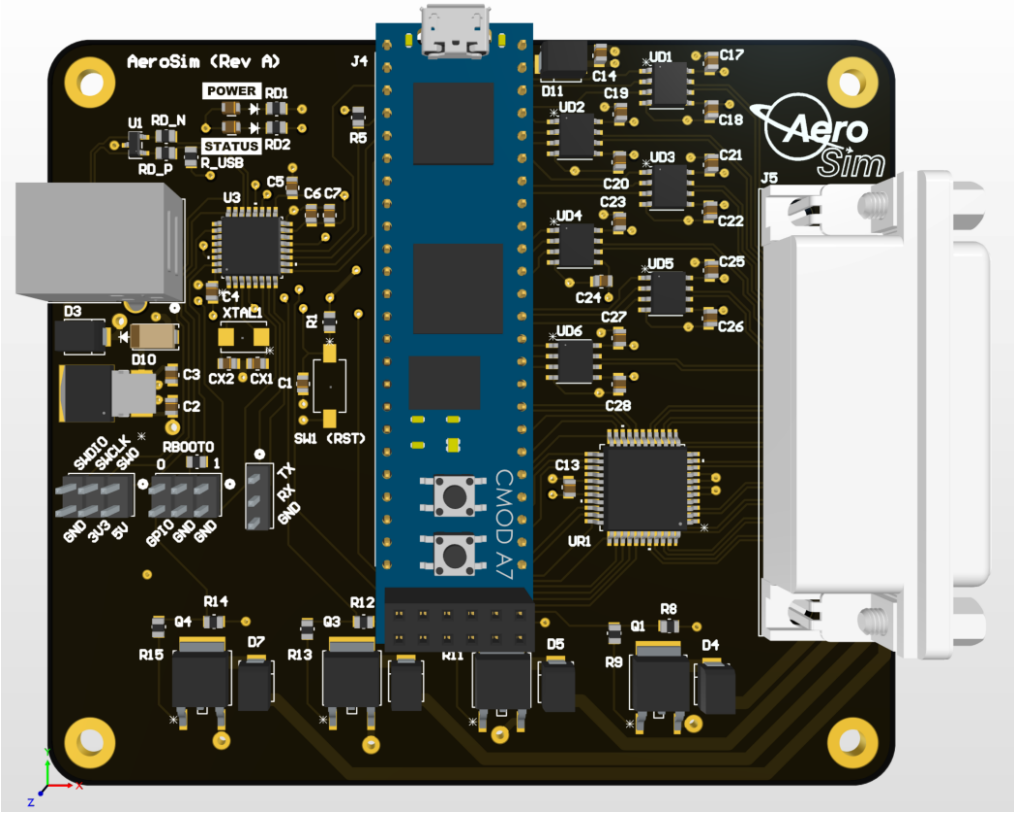
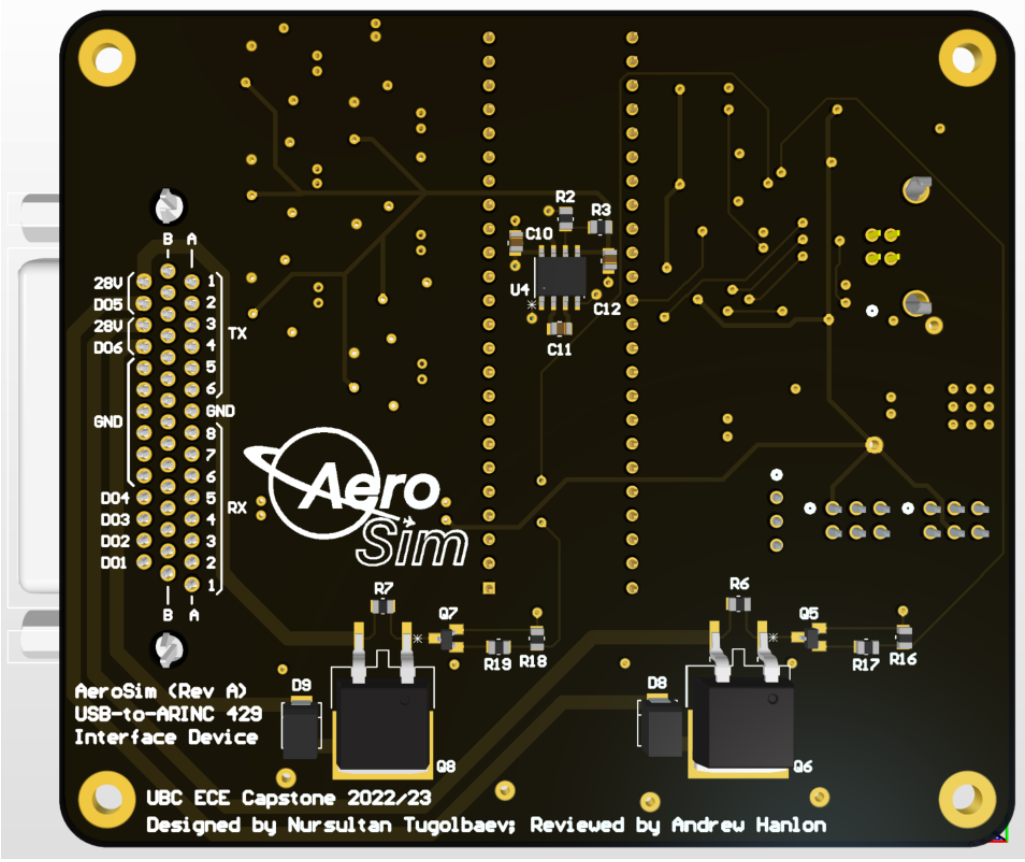


Figure A.3 - ARINC 429 bit encoding and timing for a “1” bit followed by a “0” bit.

Appendix C: PCB Screenshots




AeroSim (Rev A)
J4
POWER
RD1
STATUS
RD2
R_USB
RD_N
RD_P
U1
U3
XTAL1
D3
D10
SWDIO
SWCLK
GND
RBOOT0
3V3
5V
GPIO
TX
RX
SW1 (RST)
CMOD A7
J5
UR1
R14
R12
R8
Q4
Q3
Q1
R15
R13
R9
D7
D5
D4
Aero
Sim


B A
28V
D05
28V
D06
GND
D04
D03
D02
D01
TX
RX
GND
R2
R3
C10
U4
C12
C11
R7
Q7
R19
R18
R6
Q5
R17
R16
D9
D8
Q8
Q6
AeroSim (Rev A)
USB-to-ARINC 429
Interface Device
UBC ECE Capstone 2022/23
Designed by Nursultan Tugolbaev; Revieved by Andrew Hanlon

Appendix E: Team Information

Name	Initials	Tech Lead	Management Lead
Anthony Wang	AW	GUI software (front end)	Deliverable Organiser
Nursultan Tugolbaev	NT	Hardware	Internal Discussions / Meetings
Patric McDonald	PM	GUI software (back end)	Treasurer Minute taker
Andrew Hanlon	AH	Firmware	Client Communication
Isabelle André	IA	Digital logic design	Internal/External Communications

Appendix F: Project Report Contributions

Section	Major Content	Minor Content	Author	Reviewer
1	IA	NT AH	IA	PM NT AH
2.1, 2.2, 2.4	IA NT	NT	IA	PM NT AH
2.3, 2.5	PM AH	NT	PM AH	AW NT AH
3, 3.1, 3.2	IA	PM	IA	PM

	PM AW		AW	AH
4.1, 4.2	IA PM		IA	PM AW AH
5	NT		NT	AH
Appendices	AH NT		AH NT	PM
All sections formatting	AW IA	AW	AW IA	IA

Appendix G: References

[1] *Digital Information Transfer System (DITS) Part 1 Functional Description, Electrical Interfaces, Label Assignments And Word Formats*, ARINC Specification 429P1-18, AEEC, Maryland, USA, Nov. 29, 2012.

[2] “Defined Class Codes,” usb.org, [Online]. Available: https://www.usb.org/defined-class-codes. Accessed Feb. 1, 2023.

[3] B. Waldmann, *ARINC 429 Tutorial Manual*, version 2.2. AIM, Freiburg, Germany, Jul. 2019. Accessed: Nov 2, 2022. [Online]. Available: https://www.aim-online.com/wp-content/uploads/2019/07/aim-tutorial-oview429-190712-u.pdf

[4] ST Electronics, *STM32G431KBT6 Datasheet*, DS12589 Rev 6, AIM, Geneva, Switzerland, Oct. 2021. Accessed: Jan 3, 2023. [Online]. Available: https://www.st.com/resource/en/datasheet/stm32g431cb.pdf