Particle Analysis and Display System (PADS):

ARINC 429 Module Manual

DOC-0272 Rev A

PADS 3.7.2

ARINC Module 3.7.0

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Trademark Information

Risks of Installing Additional Software

Instrument computers from DMT are configured to acquire data in a reliable, robust manner. Typically, such instruments are either not connected to a network or are connected to a small, local network that is isolated from the internet, reducing the risk of viruses. Since anti-virus programs can cause erratic behavior when run in the background on data acquisition computers, DMT does not install anti-virus, anti-spam, or anti-malware programs. If you choose to install these programs, you accept the risk associated with them in terms of potential performance degradation of the software installed by DMT.

For similar reasons, DMT recommends that you do not install or run other software on the dedicated instrument computer. Although the installation of some software may be unavoidable, it is particularly important not to run other software while the computer is acquiring data.

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1.0 Introduction

The Particle Analysis and Display System (PADS) is a software package that interfaces with instruments produced by Droplet Measurement Technologies (DMT) and other leading instruments used in the atmospheric sciences. This manual describes PADS ARINC 429 version 3.7.0, which allows you to feed selected data to an ARINC 429 port for use with an external data system.

For an explanation of the basic PADS setup and instructions on how to acquire data using PADS, consult the *PADS Overview Manual*, DOC-0300. This manual also gives definitions for all the channels that Serial Output module can send over the serial stream.

The ARINC 429 tab is accessible from the **Summary** tab. (Note that this tab may be called something other than Summary if you have renamed it.) For more information about other Summary sub-tabs (XY Plots and Numeric, Histogram Summary, XYZ Color Plots, and Summary Array), consult DOC-0299, the *PADS Summary Module Manual*.

2.0 Configuring the Display

Because the ARINC 429 tab displays data from several different instruments, you cannot use the ARINC 429 screen to configure instruments. Therefore, the **Configure Instrument** option on the **Configure** menu has been grayed out. If you want to configure an instrument that has data displayed in the ARINC 429 tab, click on that instrument's tab in PADS and select **Configure Instrument**.

To configure the ARINC 429 display and the ARINC 429 data transmission settings, follow the steps below.

1. Click on the "Summary" tab (or whatever your Summary tab is called).
2. From the **Configure** menu, select **Configure Display.**
3. Click on the **ARINC 429** tab. You will see the following window.

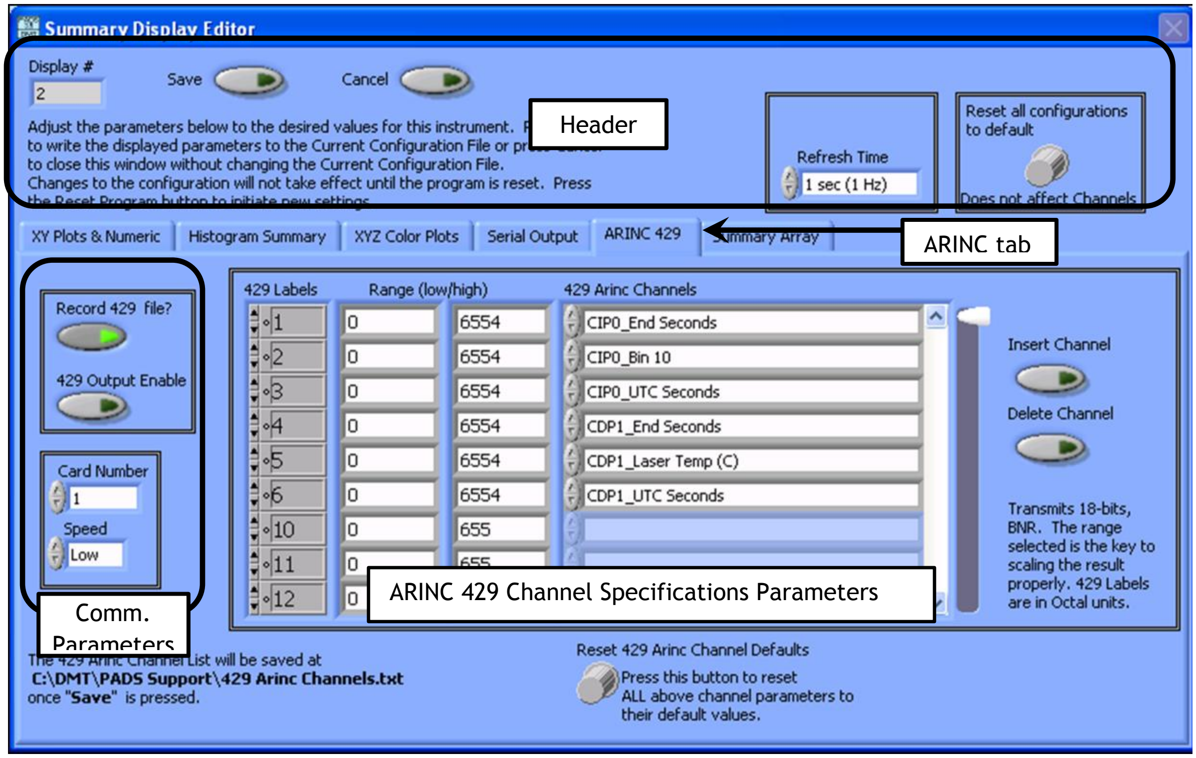


Figure 1: ARINC 429 Display Editor Window

2.1 Parameters in the Header (apply to entire Summary Display)

You do not need to modify the **Display #.**

Changing the **Refresh Time** allows you to set the time intervals for data display during acquisition mode. You can choose any time that is equal to or greater than the instruments' sample times. (Choosing a time less than the sample time is not useful, since the same data will be displayed and sent over the ARINC 429 port multiple times.) If the instruments displayed on the ARINC 429 tab have different sampling times, setting the refresh time to that of the fastest sample time will give the best results. In addition, the Refresh Time also specifies the time interval at which the ARINC 429 data is sent over the ARINC 419 port.

2.2 ARINC 429 Parameters

2.2.1 Communications Parameters

If **Record 429 File?** is illuminated, ARINC 429 data are recorded to a .csv output file. When this button is on, the computer will record the channels specified in the 429 Arinc Channels table.

The **429 Output Enable** button allows users to specify whether data should be sent over the ARINC 429 port. When this button is off, no data are sent. When it is on, the computer will relay the channels specified in the 429 Arinc Channels table. The **429 Output Enable** setting selected on the Display Editor will be the default setting when PADS opens. However, you can change the setting for the current sampling instance only by using the same button on the main ARINC 429 window.

The **Card Number** specifies the number of the plug-in card in the computer hardware.

The **Speed** field indicates whether ARINC 429 data is transmitted at high speed (100 Kb/sec) or low speed (12.5 Kb/sec).

2.2.2 ARINC 429 Channel Specifications

The **ARINC 429 Channel Specifications** table allows you to configure and specify channel data to be sent over the ARINC 429 port.

The **429 Labels** column indicates the label used to identify a channel in the ARINC 429 data stream. Each label must be unique, although labels do not need to be listed in a consecutive order on the Display Editor screen. Note that the default telemetry channels' labels do not necessarily conform to industry standards, while industry standard assigns label 204 to barometric altitude. Likewise, users are free to assign labels to PADS channels as they choose, so long as the same label is not assigned to multiple channels.

The **Range (low/high)** fields specify how PADS encodes the real numbers recorded in data channels into the positive-integer format that the ARINC 429 device requires. Likewise, after transmission the range information is useful in decoding ARINC 429 data in an external data system.

The PADS encoding uses the following conventions:

- For ranges with a low of 0 and a high of 65, an ARINC 429 value of "ABCDE" denotes a real number AB.CDE, where AB <= 65.
- For ranges with a low of 0 and a high of 655, an ARINC 429 value of "ABCDE" denotes a real number ABC.DE, where ABC <= 655.
- For ranges with a low of 0 and a high of 6553, an ARINC 429 value of "ABCDE" denotes a real number ABCD.E, where ABCD <= 6553.
- For ranges with a low of 0 and a high of 65553, an ARINC 429 value of "ABCDE" denotes a real number ABCDE, where ABCDE <= 65535.
- If a channel's value must include negative numbers, the high range should be ½ that shown above, and the low range should be the negative of the high range. Thus a channel that could have values from -60 to +120, such as a temperature,

should use the values -327 and 327 for the high and low ranges, so that values such as –ABC.DE to +ABC.DE can be transmitted.

Note: PADS uses the above conventions even though the ARINC 429 port actually uses 18 bits (for range of 0 – 262143) rather than 16 bits (for a range of 0 – 65535).

The **429 Arinc Channels** column allows you to specify the channels to be sent out over the ARINC device. Clicking on a row in this column brings up a list of all available channels, as shown in the figure below.

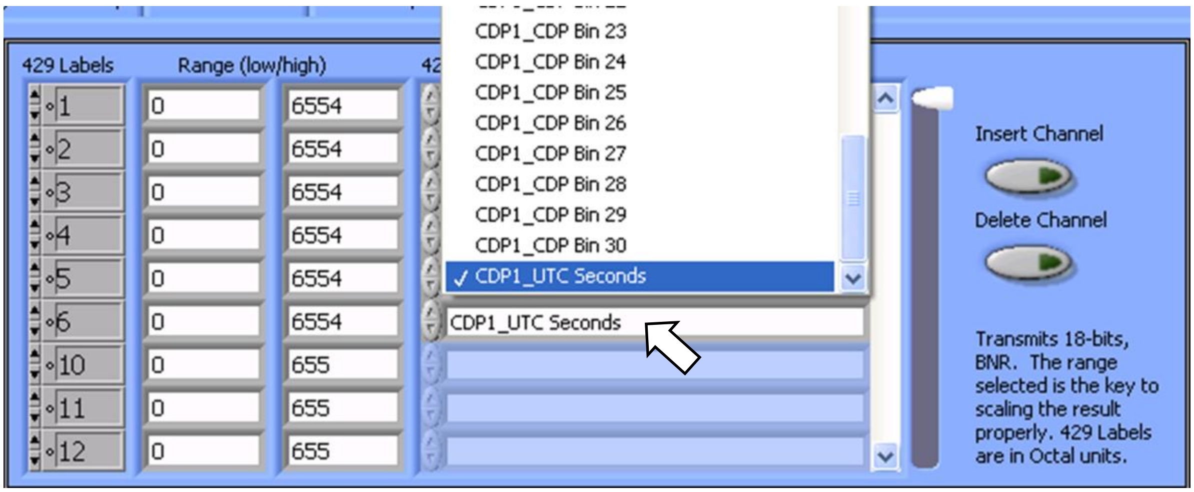


Figure 2: Selecting ARINC 429 Channels

You can add and delete ARINC 429 channels using **Insert Channel** and **Delete Channel** buttons. The scrollbar to the right of the 429 ARINC Channels column allows you to move quickly through the list of available channels. The cursor to the right of the scrollbar allows you to specify where channels should be inserted or deleted. For instance, if the cursor is set as in Figure 3, pressing the **Delete** button would delete the telemetry channel **CIP0_Bin 10**.

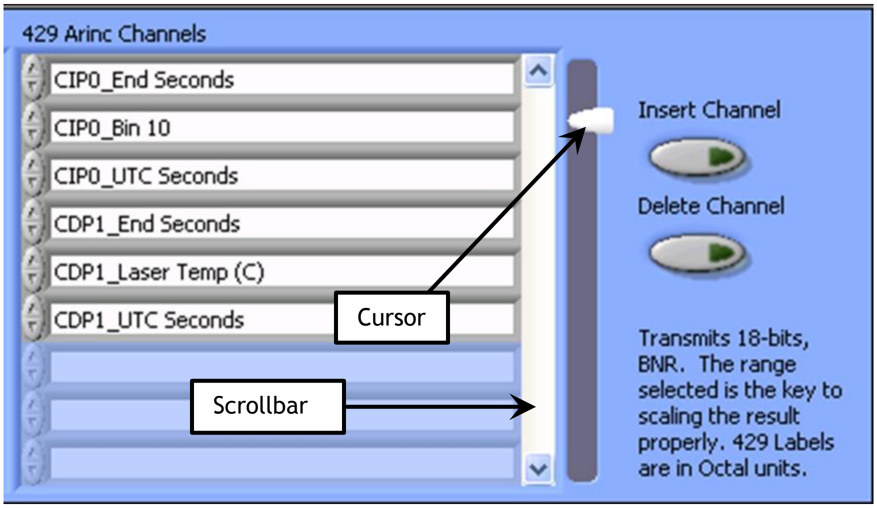


Figure 3: ARINC 429 Channels Scrollbar and Cursor

PADS stores the telemetry channel names in `C:\DMT\PADS Support\ 429 Arinc Channels.txt`. This file is updated every time you change and save the Telemetry Display configuration. The file is a simple ASCII text file, and it is an output file only. The programmer of the data system that will be receiving the ARINC 429 data can use this file to determine the formatting of the channels being sent. There is no mechanism for importing this channel list into PADS, so there is no need to edit this file. It is for reference only.

Pressing the **Reset 429 Arinc Channel Defaults** button will set the all the 429 Arinc channels and their corresponding labels and ranges to the default values. These values are designed for a Cloud Imaging Probe (CIP). If the Reset 429 Arinc Channel Defaults button is pressed when PADS has a different configuration than the CIP, the resulting channels will have little relevance to what should actually be configured.

Pressing the **Set 429 Arinc Channels** button allows you to set the currently displayed 429 Arinc channels as the default values. When you click this button, an instance of Windows Explorer will open so you can designate an .ini file in which to store these defaults.

When you are done changing parameters on the **Display Editor** window, click on **Save** to update the configurations or **Cancel** to revert to the previous configurations. After you reset PADS, you will be able to see any changes by viewing the ARINC 429 display. Note that clicking **Reset Program** will clear out any data currently being displayed.

3.0 The ARINC 429 Window

The ARINC 429 window displays channel data is shown below.

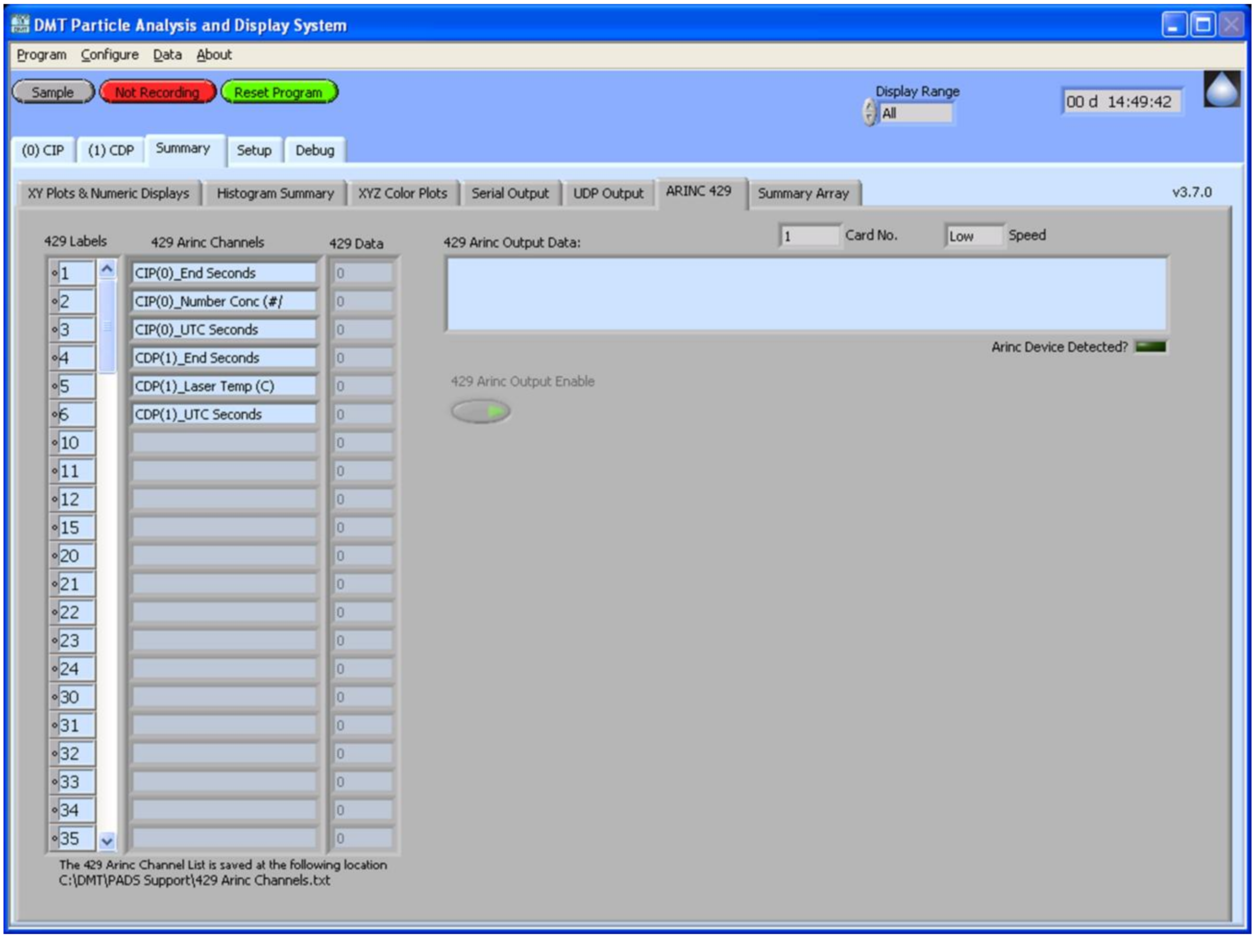


Figure 4: ARINC 429 Main Window

ARINC 429 channel data appear on the left side of the window. During acquisition mode, the **429 Output Enable** button allows you to start or stop the telemetry data feeding to the ARINC 429 port. (Clicking this button during playback mode has no effect.) When the button is on and the system instruments are sampling, any channels listed in the **429 Arinc Channels** fields are fed in a serial data stream to the ARINC 429 port. You can then capture this data using an external system. PADS also displays the current values for these channels in the **Data** field on the far right of the Telemetry screen.

To add and delete telemetry channels, go to **Configure > Configure Display** and modify the telemetry channels listed on the right of the **Display Editor** screen.

For information on specific channels, their definitions, and their acceptable ranges, consult *PADS Overview Manual*'s *Appendix A: Definitions*.

The **429 Labels** column indicates the label used to identify a channel in the ARINC 429 data stream. For more information on labels and how to change them, see section 2.2.2.

The **429 Data** column lists channel values for the current moment in time.

The **Card No.** specifies the number of the plug-in card in the computer hardware. The **Speed** field indicates whether ARINC 429 data is transmitted at high speed (100 Kb/sec) or low speed (12.5 Kb/sec). Both of these settings can be configured from the Display Editor; see section 2.2.1.

429 Arinc Output Data displays the current string that is being sent out.

The **Arinc Device Detected?** Indicator light illuminates when the system has detected the ARINC 429 device.

Appendix A: ARINC 429 Data Bus Characteristics

ARINC 429 is the most common data bus for commercial aircraft. It has the following characteristics:

- Data are transmitted uni-directionally in 32-bit words over bipolar RZ format.
- Common data types are BCD and BNR, which are described below.

Electrical Characteristics

Nominal transmission voltage is 10 ± 1 volts differential, using bipolar return-to-zero modulation.

- HI is nominally between 7.25 to 11 volts.
- LO is -7.25 to -11 volts.
- NULL is 0.5 to -0.5 volts.
- Slew rate:
  - High speed: 1.5 ± 0.5 µsec
  - Low speed: 10 ± 5 µsec

Data Protocol

- Point to point
- 12.5 or 100 Kb/sec
- Tx and Rx on separate lines
- One Tx, 1 – 20 Rx
- One Tx per line
- 32-bit words
- 4 NULL (zero voltage) bits between words
- Typically one word per packet, although up to 512 are possible
- Label field defines data type

Data Fields

There are five primary fields:

- Parity bit (1 bit)
- Sign/Status Matrix (SSM) (2 bits – determines if number is signed or unsigned)
- Sign (S) (1 bit – determines whether number is positive or negative, if signed)
- Data (18 bits)
- Source Destination Indicator (SDI) (2 bits)
- Label (8 bits)

These fields are described in more detail below.

MSB LSB

<table>
<tr><td>32</td><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>P</td><td colspan="2">SSM</td><td>S</td><td colspan="18">DATA (MSB) ⟶ (LSB) ⟵ DISCRETES ⟵ PAD</td><td colspan="2">SDI</td><td colspan="8">LABEL (LSB) ⟶ (MSB)</td></tr>
</table>

Parity

ARINC 429 uses an odd parity bit, meaning the parity bit will toggle to create an odd number of ones in the word.

Sign/Status Matrix (SSM)

This field contains the hardware status, operation mode, or data validity. The field varies based on the data type, which is determined by the device. (The Label field indicates which device is being used.)

For BCD data type:

00	Plus, North, East, Right, To, or Above
01	No Computed Data
10	Functional Test
11	Minus, South, West, Left, From, Below

For BNR data type:

00	Failure Warning (can occur even during normal operation), or unsigned
01	No Computed Data
10	Functional Test
11	Normal Operation, or signed

Data

The 18 bits may overrun the Source Destination Indicator (SDI) for extra precision. Common data types are BCD, BNR, Discrete, Maintenance, Acknowledgment, and Character data.

The two most common data types are:

Two's-Complement (BNR) is the most common format, and the one used by DMT. This encoding stores the data in binary form. Bit 29 is the sign bit (positive or negative), and bit 28 is the MSB. The MSB represents half the maximum data value, with each successive bit representing half the preceding bit's value. Negative values are found by inverting all bits and adding one to the least significant bit.

Binary Coded Decimal (BCD), which encodes decimal values in four-bit blocks. Due to size limitations, when transmitting five digits, the most significant digit is limited to decimal value seven; however, transmitting four digits removes this limitation.

Source Destination Indicator

In a system with multiple receivers, this field identifies the destination of packets. In a complex system, it can be used to identify the transmitter. Occasionally it is used for data.

Label

The label identifies the data type and accompanying parameters. It is typically represented in octal form.

How DMT Uses the ARINC 429

The entire data packet (**Data, Label, SDI,** etc.) is transmitted from LSB to MSB, meaning the Label field is received first and the parity bit last.

PADS can be used to set the ARINC 429 transmission rate; see the description of the **Speed** button in section 2.0. The **Label** fields in PADS allow users to assign specific data from attached probes. This is described in the “ARINC 429 Channels” section.

As stated above, DMT uses BNR/two’s-complement for the **Data** field. The data are stored in 18 bits (not including the sign bit) with zero padding. Two's complement values use sign extension such that positive values are preceded by 0’s and negative values with 1’s. Bit 11 is the LSB of the data portion and is typically a fractional value. Bit 29 stores the sign. It is unused for unsigned values, and remains a zero. For signed values, it is a one.

Fractions are represented as $1/2^x$, where x is a position relative to the decimal point.

Examples Converting Negative Numbers to Two’s Complement

One can calculate a two’s complement version of a binary number by inverting all the bits and adding a single bit to the LSB of the entire data block.

-1_{10} = -0001_2 → $1110_2 + 1_2$ = 1111_2

-1.5_{10} = -01.10_2 → $10.01_2 + .01_2$ = 10.10_2

-3.75_{10} = -11.11_2 → $00.00_2 + .01_2$ = $(1)00.01_2$

-16.25_{10} = -00010000.0100_2 → $11101111.1011_2 + .0001_2$ = 11101111.1100_2

Examples of How Numbers are Padded for Different Scales

When sending the value 1.5 across Arinc429 we receive the following values according to scaling:

Scaling:	Binary Value:	
0 to 6	000110000000000000	The LSB for Integer Data is bit 26
0 to 65	000000011000000000	The LSB for Integer Data is bit 22
0 to 655	000000000110000000	The LSB for Integer Data is bit 19
0 to 6553	000000000000110000	The LSB for Integer Data is bit 16
0 to 65535	000000000000000110	The LSB for Integer Data is bit 13
-32 to 32	000001100000000000	The LSB for Integer Data is bit 24
-327 to 327	000000000110000000	The LSB for Integer Data is bit 20

When sending 1.25:

Scaling:	Binary Value:	
0 to 6	0001010000000000000	The LSB for Integer Data is bit 26
0 to 65	0000000101000000000	The LSB for Integer Data is bit 22
0 to 655	0000000000101000000	The LSB for Integer Data is bit 19
0 to 6553	0000000000000101000	The LSB for Integer Data is bit 16
0 to 65535	0000000000000000101	The LSB for Integer Data is bit 13
-32 to 32	0000010100000000000	The LSB for Integer Data is bit 24
-327 to 327	0000000001010000000	The LSB for Integer Data is bit 20

When sending 1.29:

Scaling:	Binary Value:	
0 to 6	0001010010100011110	The LSB for Integer Data is bit 26
0 to 65	0000000101001010001	The LSB for Integer Data is bit 22
0 to 655	0000000000101001010	The LSB for Integer Data is bit 19
0 to 6553	0000000000000101000	The LSB for Integer Data is bit 16
0 to 65535	0000000000000000101	The LSB for Integer Data is bit 13
-32 to 32	0000010100101000111	The LSB for Integer Data is bit 24
-327 to 327	0000000001010010100	The LSB for Integer Data is bit 20

The first bit in any of these values is zero, because the values are all unsigned numbers. This bit does not carry data.

When sending -1.5:

Scaling:	Binary Value:	
-32 to 32	1111101000000000000	The LSB for Integer Data is bit 24
-327 to 327	1111111110100000000	The LSB for Integer Data is bit 20

These are in two’s complement.

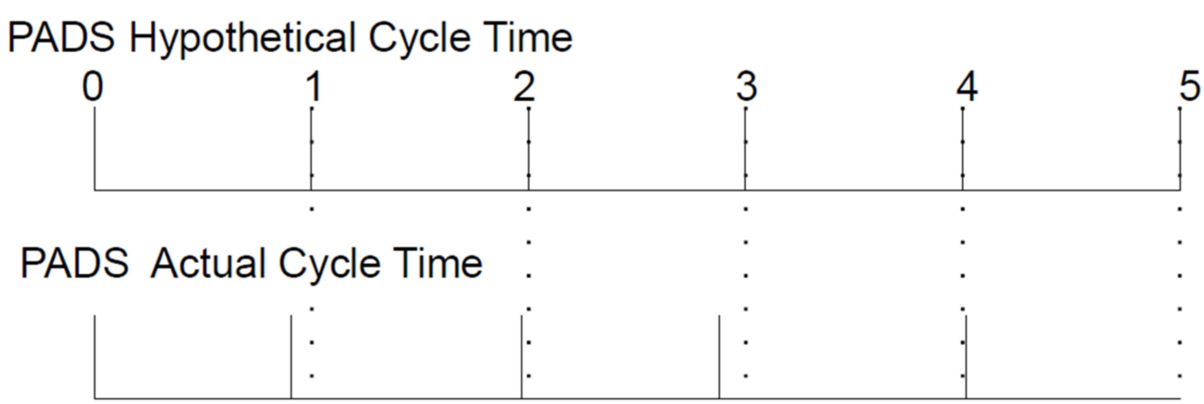
Appendix B: ARINC 429 Transmission Issues

Timing Issues

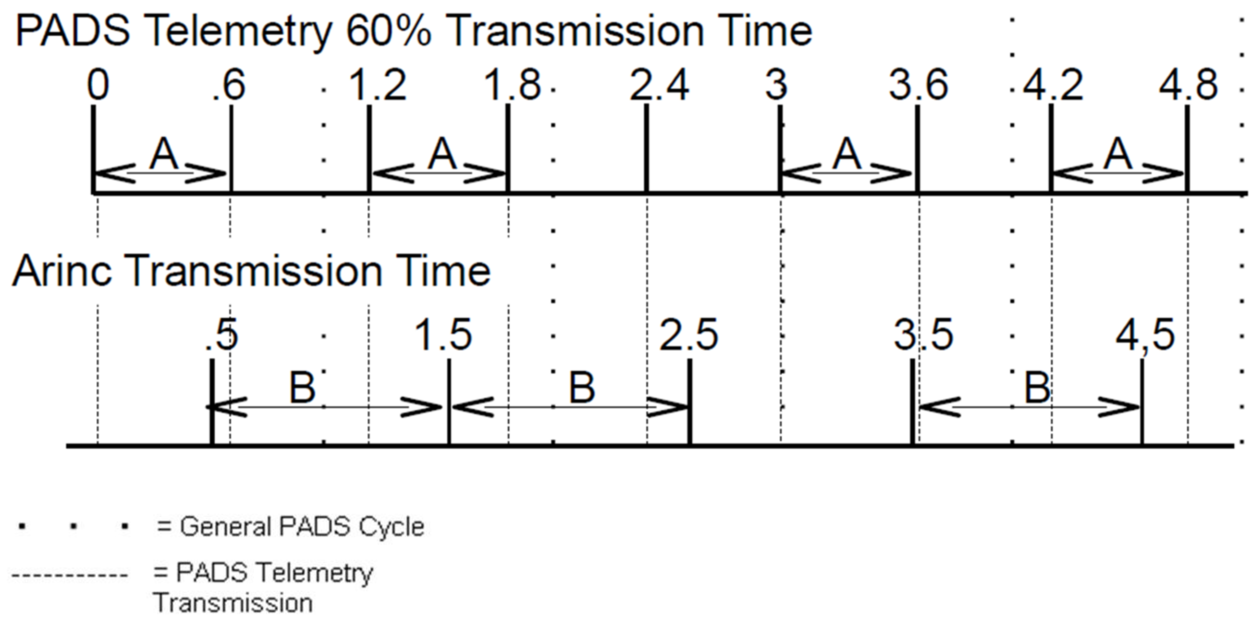
There are four separate data transmissions that occur when an ARINC 429 adapter is used with PADS and a DMT probe. Data are first transmitted from the probe to the PADS computer instrument module, then from the PADS instrument module to the PADS 429 module, then from PADS 429 module to the ARINC 429 device, and finally from the ARINC 429 device to the ultimate destination.

The last of these transmissions occurs at a precise interval, since the ARINC 429 adapter transmits data every second, independently of the data received. The timing of the second and third transmissions are more variable. Due to the timing issues internal to any user space program, there are small changes to the clock cycle in PADS. This means that the sample time set by the user may be off by up to 2%.

While seemingly small, this inconsistency in timing means there are issues when sending synchronous data to the external source. This is illustrated by the figure below, where PADS cycles are depicted with the solid lines. If the ARINC device transmits data exactly every second (i.e., on the dotted lines) then some of the PADS-generated data will be missed, while some samples will be sent twice.



To avoid this problem and ensure that the adapter is sending the most current data, PADS updates the telemetry data at 95% of the normal clock cycle. This ensures that for the vast majority of transmissions, the ARINC device has the most up-to-date information. However, this scheme introduces a constant drift between the PADS transmission and the ARINC transmission. This drift in turn results in two new complications. These are shown in the following figure, which illustrates the effect with a PADS telemetry transmission rate of 60% (rather than the actual 95%) to highlight the problem.



In the cases marked with an "A," two PADS telemetry transmissions occur within a single cycle of the general PADS cycle. This results in duplicate data being sent to the ARINC.

A second potential problem results in data being lost. In the cases marked with a "B," two PADS telemetry transmissions occur within a single ARINC transmission cycle. This means that the first set of data are never transmitted from the ARINC. In some instances, e.g. with the two PADS samples that are transmitted between 1.5 and 2.5 seconds, the first PADS sample is actually a duplicate of the previous sample, which was already sent at 1.5 seconds. In this instance, it does not matter that this transmission is lost. In other cases, however, the ARINC has not yet sent the first PADS data packet, and these data are completely omitted from the final serial stream.

Processor Overload Issues

The second issue regarding the ARINC to USB conversion is lost packets due to processor overload. When running PADS in conjunction with the ARINC adapter, it is possible to overload the CPU, particularly when an imaging probe is acquiring a high concentration of particle images. This results in lost packets due to lost cycles. To reduce the possibility of lost packets, the number of channels transmitted must be limited.

For an ADL PC 104 stack (as is typically used in a DMT APDS (Airborne Power Distribution System)), operating a probe without any particles, it is possible to transmit 150 channels per second from the 429_telemetry tab. However, at normal operating levels, the probe can only handle 128 channels. When running the spinning disk image test device at full speed, a maximum of 110 channels is recommended. (With a more powerful processor, additional channels may be possible.) These limits will minimize dropped packets from overload.

Appendix C: Revisions to Manual

This document replaces DOC-0233, the *PADS 2.X ARINC 429 Operator Manual*. All sections have been updated.