
Particle Analysis and Display System (PADS): 429 Telemetry Module

Operator Manual

DOC-0233 Rev C

PADS 2.8.2

429 Telemetry Module 2.8.0



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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 all the instruments produced by Droplet Measurement Technologies (DMT) and other leading instruments used in the atmospheric sciences. This manual describes the PADS module for the 429 Telemetry display. The 429 Telemetry display allows you to view and analyze data from several instruments simultaneously. It also 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 Operator Manual, DOC-0116*. This manual also gives definitions for all the channels that the 429 Telemetry tab can display.

2.0 Configuring the Display

Because the 429 Telemetry tab displays data from several different instruments, you cannot use the 429 Telemetry 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 429 Telemetry tab, click on that instrument's tab in PADS and select **Configure Instrument**.

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

1. Click on the “429 Telemetry” tab.
2. From the **Configure** menu, select **Configure Display**. You will see the following window.

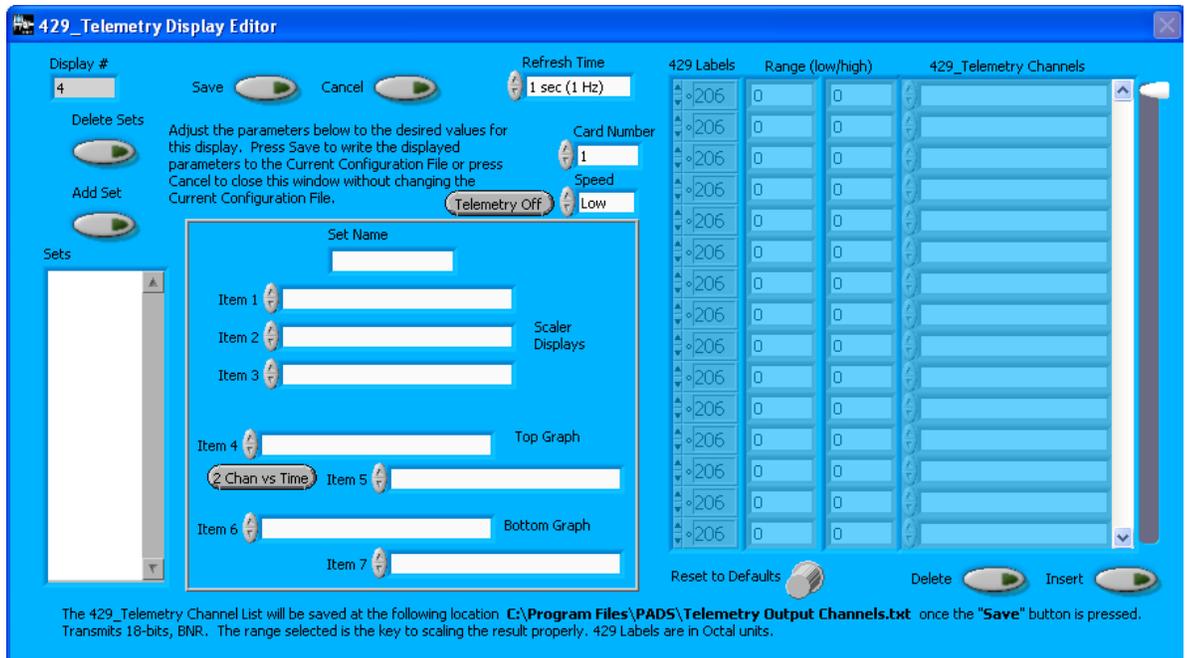


Figure 1: 429 Telemetry Display Editor Window

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 429 Telemetry port multiple times.) If the instruments displayed on the 429 Telemetry 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 429 Telemetry data is sent over the ARINC 419 port.

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).

The **Telemetry On/Off** button allows users to specify whether data should be sent over the ARINC 429 telemetry port. When this button is off, no data are sent. When it is on, the computer will relay the channels specified in the 429_telemetry channels in the far right table. The Telemetry On/Off 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 429 Telemetry window.

Selectable Charts and Tabular Data Displays

The Display Editor allows you to define sets of data that the 429 Telemetry window displays. A set is basically a single configuration of the 429 Telemetry window. It specifies items 1-7 that PADS uses in this display. (Figure 4 illustrates where these items appear on the 429 Telemetry display.) Note that any set can include channels from any instrument in the system. For instance, you might define a set called “LWC” that displays and graphs LWC readings from various instruments. For information on channels and their definitions, see *Appendix A of the PADS Operator Manual, DOC-0116*.

The button to the left of item 5 allows you to specify how a given set should graph items 4 and 5—with respect to each other, or with respect to time.

The box in the bottom left of the Display Editor lists all the available data sets. You can add sets and delete sets using the buttons above the box. When you add a set, you specify the set name and all the item numbers using the controls in the box at the bottom center of the display editor.

Note that all of these chart and channel parameters are also changeable from the 429 Telemetry main window, as discussed in section 3.0. Changing the parameters directly on the 429 Telemetry display changes them for the current session only, while changing them here on the Display Editor window creates parameter sets that are also available in future sessions.

429 Telemetry Channels

The **429 Telemetry Channels** table to the right of the screen allows you to specify channel data to be sent over the ARINC 429 port. Clicking on a row in the 429 Telemetry Channels table brings up a list of all available channels, as shown in the figure below.

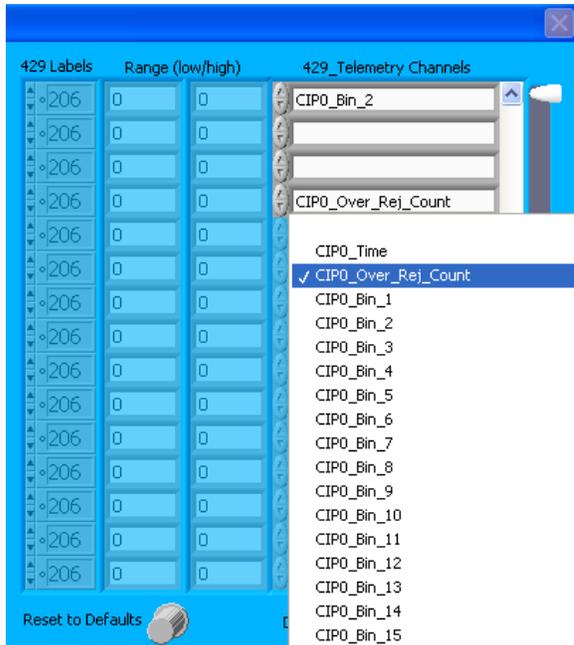


Figure 2: Selecting 429 Telemetry Channels

Using 429 telemetry channels allows you to capture these data using an external system. You can add and delete 429 telemetry channels using the buttons beneath the channels list. The scrollbar to the right of the 429_Telemetry 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 **CCP Summary3_TotalED**.

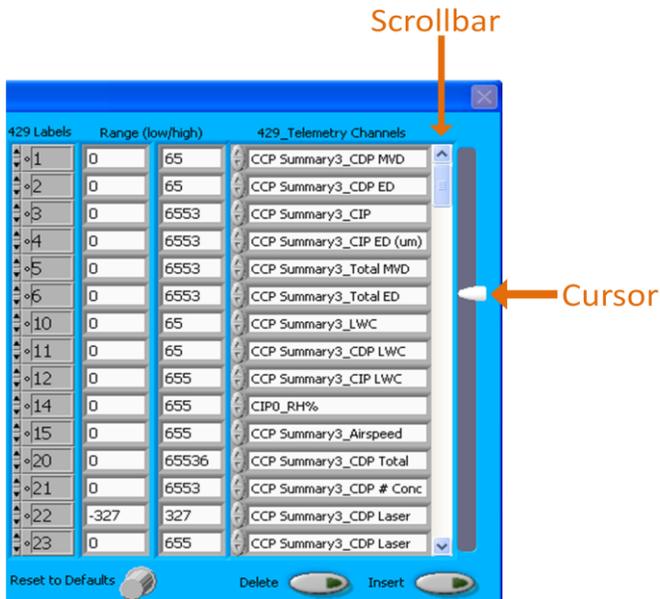


Figure 3: 429 Telemetry Channels Scrollbar and Cursor

PADS stores the telemetry channel names in C:\Program Files\PADS\Telemetry Output 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 429 Telemetry 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 to Defaults** button will set the telemetry channels and their corresponding labels and ranges to the default values. These values are designed for a Combination Cloud Probe (CCP) configuration, with the first four PADS tabs assigned to the Cloud Imaging Probe (CIP), Cloud Droplet Probe (CDP), Hotwire Liquid Water Content Sensor (LWC), and CCP Summary tab, respectively. If the **Reset to Defaults** button is pressed when PADS has a different configuration than stated here, the resulting channels will have little relevance to what should actually be configured.

The **429 Label** 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—for instance, label 204 identifies the default channel **CCP Summary3_CIP Bin 5** in PADS, 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 429 telemetry 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 <= 65553.
- 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).

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 429 Telemetry display. Note that clicking **Reset Program** will clear out any data currently being displayed.

3.0 The 429 Telemetry Window

The 429 telemetry window displays channel data in numeric and graphical form. It also provides information on the currently selected telemetry channels and whether telemetry is on or off.

Numeric Data

The top of the Telemetry window displays three time-specific channels in numeric form. These channels correspond to Items 1 - 3 on the Display Editor window (see Figure 1). PADS displays the data values just to the right of the field listing the data channel names.

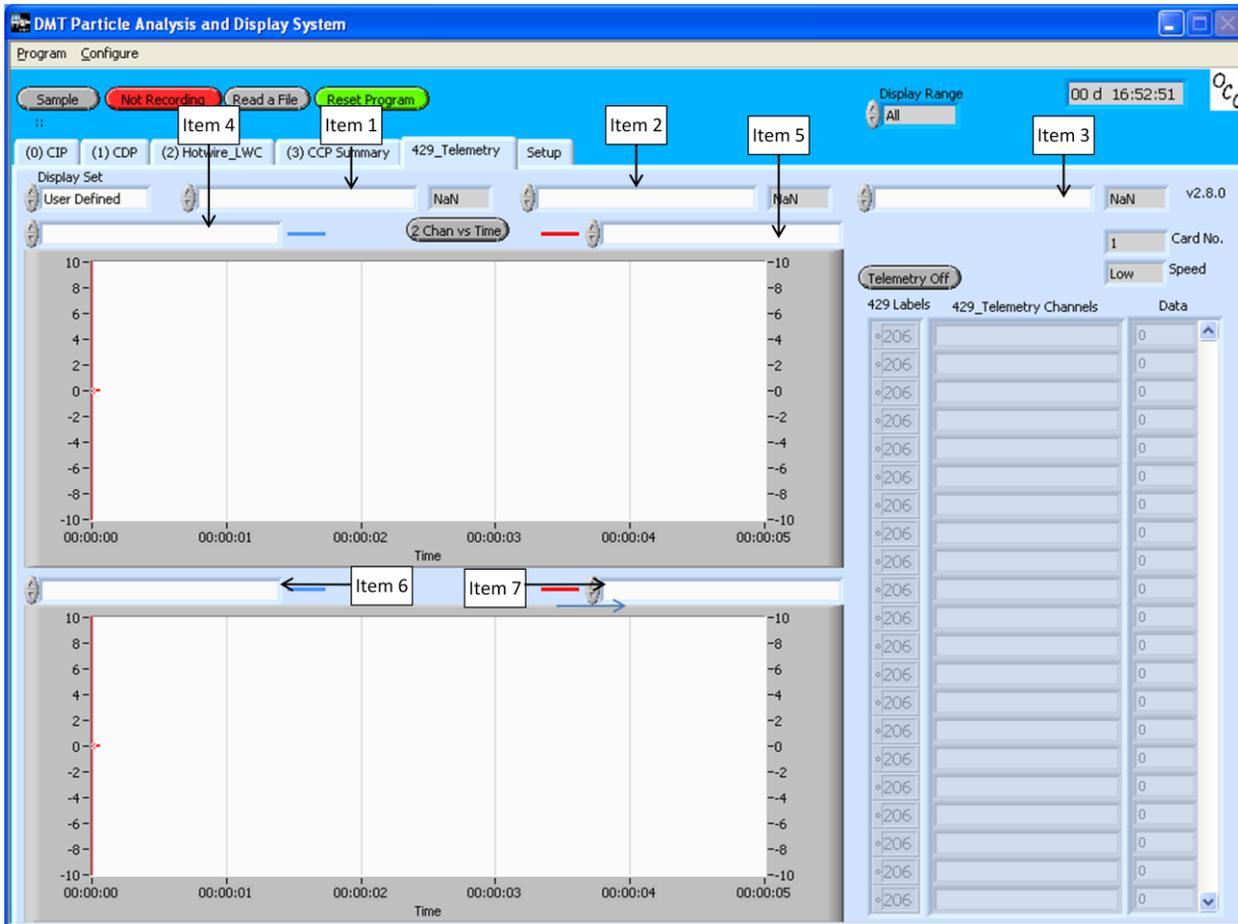


Figure 4: 429 Telemetry Main Window

Chart Displays

The telemetry window contains two graphs. Items 4 and 5 determine the channels PADS charts in the top graph. By default, PADS charts both of these channels with respect to time. Item 4 is displayed in blue and has its legend on the left side of the graph. Item 5 is charted in red and has a legend on the graph's right side.

You can change default time-series setting upon start-up by pressing the **2 Chan vs. Time** button on the Display Editor screen. This changes the button so it reads **Chan vs. Chan**, and the Telemetry's top graph displays the two channels charted with respect to each other. The **Chan vs. Chan** option charts Channel 4 on the x axis and Channel 5 on the y axis.

Items 6 and 7 determine the channels PADS charts in the bottom graph. Item 6 is displayed in blue and has its legend on the left side of the graph. Item 7 is charted in red and has a legend on the graph's right side.

If you have created sets on the Display Editor screen (see section 2.0), you can display these pre-specified channels by selecting the desired set in the **Display Set** control in the upper left of the screen. You can also change the channels being displayed by directly editing the item fields shown in Figure 4. If you modify the item fields this way, the **Display Set** value changes to “User Defined.” You can revert to a pre-defined set by selecting that set in **Display Set**.

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

When you access time-series charts in playback mode, the currently selected moment in time is indicated by a red cursor. The y-axis value for this time is indicated by cross (+) on this cursor. This y-axis value is always for the channel listed on the left side of the graph, i.e. the one that PADS displays in blue.

Note that when you display a large range of time-series data, the chart display does not have sufficient resolution to display each individual time point. To increase resolution, zoom in on the data by changing the time interval to a smaller range.

On both the top and bottom charts, you can change the scale by typing a different number into the starting and ending values on each axis.

The charts also show you options for scaling and copying the data when you right-click on the graph. These options are as follows:

Autoscale X / Autoscale Y Right-clicking on an axis brings up an autoscaling option for that axis, which allows you to enable or disable autoscaling. Note that on the Telemetry charts, it is possible to enable autoscaling on one y-axis and disable it on the other. If you disable autoscaling, the scale of the axis will remain constant. In this case, the range will always be the same as it was when autoscaling was disabled. The minimum and maximum Y values can then be changed manually by typing new numbers into these fields. In playback mode, autoscaling will not take effect until you change the time using the time controls.

Copy Data This copies the histogram chart to the clipboard using a screen capture.

Export Simplified Image This copies a simplified image of the data to the clipboard or an output file. You can choose the format you desire—bitmap (.bmp), encapsulated postscript (.eps), or enhanced metafile (.emf). Note that when you select the .eps option, you must copy the data to a file. Unless you specify

otherwise, output files will be saved in the time-and-date-specific output file directory for the current session.

Clear Graph This lets you clear the graph of the currently displayed data points.

429 Telemetry Channels

429 Telemetry channel data appear to the right of the chart displays. During acquisition mode, the **Telemetry On/Off** button at the top of the screen 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_Telemetry 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.

Note that while the PADS 429 telemetry module does not generate its own output file, any channels listed as telemetry channels will have their data stored in the relevant instrument output file.

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 μ sec
 - Low speed: 10 ± 5 μ sec

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 | | | |
| 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| P | SSM | | S | DATA (MSB) → (LSB) ← DISCRETES ← PAD | | | | | | | | | | | | | | | | | | SDI | | LABEL (LSB) → (MSB) | | | | | | | |

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 “429 Telemetry 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.

$$\begin{aligned}
 -1_{10} &= -0001_2 \rightarrow 1110_2 + 1_2 = 1111_2 \\
 -1.5_{10} &= -01.10_2 \rightarrow 10.01_2 + .01_2 = 10.10_2 \\
 -3.75_{10} &= -11.11_2 \rightarrow 00.00_2 + .01_2 = (1)00.01_2 \\
 -16.25_{10} &= -00010000.0100_2 \rightarrow 11101111.1011_2 + .0001_2 = 11101111.1100_2
 \end{aligned}$$

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 | 00011000000000000000 | The LSB for Integer Data is bit 26 |
| 0 to 65 | 00000001100000000000 | The LSB for Integer Data is bit 22 |
| 0 to 655 | 00000000001100000000 | The LSB for Integer Data is bit 19 |
| 0 to 6553 | 0000000000000110000 | The LSB for Integer Data is bit 16 |
| 0 to 65535 | 0000000000000000110 | The LSB for Integer Data is bit 13 |
| -32 to 32 | 00000110000000000000 | The LSB for Integer Data is bit 24 |
| -327 to 327 | 0000000001100000000 | The LSB for Integer Data is bit 20 |

When sending 1.25:

| Scaling: | Binary Value: | |
|-------------|---------------------|------------------------------------|
| 0 to 6 | 000101000000000000 | The LSB for Integer Data is bit 26 |
| 0 to 65 | 000000010100000000 | The LSB for Integer Data is bit 22 |
| 0 to 655 | 000000000010100000 | The LSB for Integer Data is bit 19 |
| 0 to 6553 | 000000000000010100 | The LSB for Integer Data is bit 16 |
| 0 to 65535 | 0000000000000000101 | The LSB for Integer Data is bit 13 |
| -32 to 32 | 000001010000000000 | The LSB for Integer Data is bit 24 |
| -327 to 327 | 000000000101000000 | 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 | 00000000000000000101 | 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 | 111110100000000000 | The LSB for Integer Data is bit 24 |
| -327 to 327 | 111111110100000000 | The LSB for Integer Data is bit 20 |

These are in two's complement.

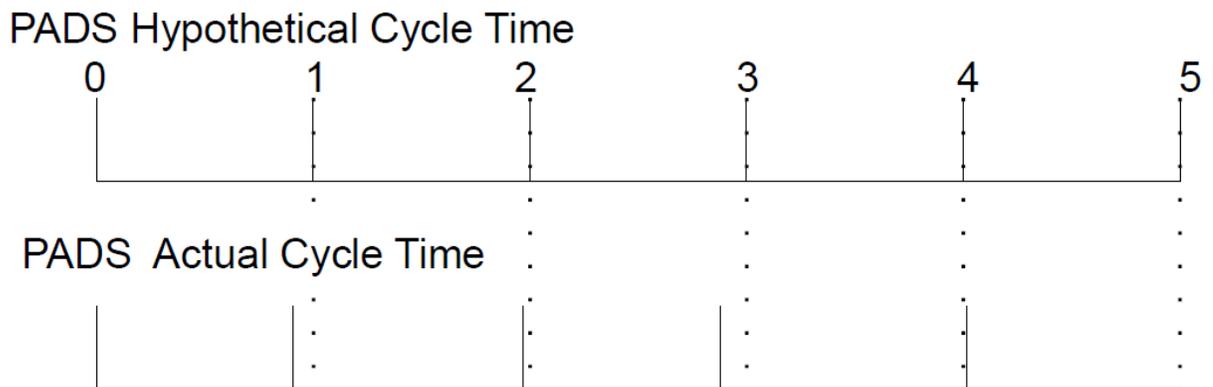
Appendix B: ARINC 429 Transmission Issues

Timing Issues

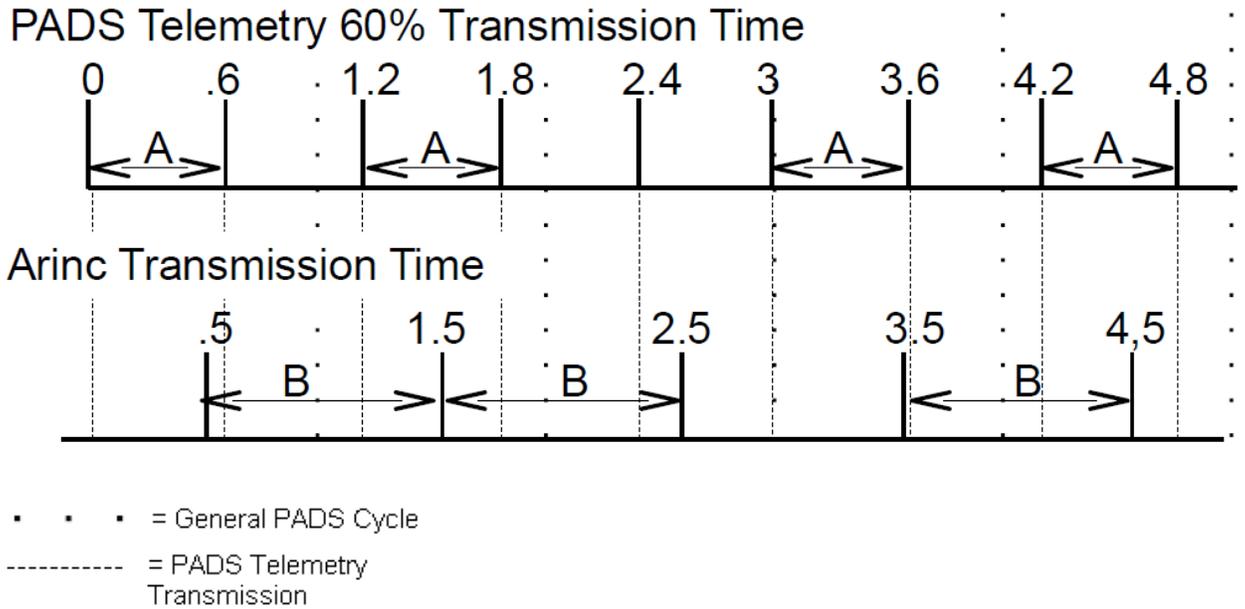
There are four separate data transmissions that occur when an ARINC 429 adapter is used with PADS and a DMT probe. Data are first transmitted from the probe to the PADS computer instrument module, then from the PADS instrument module to the PADS 429 module, then from PADS 429 module to the ARINC 429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

| Rev. Date | Rev. No. | Summary | Section |
|-----------|----------|---|------------|
| 1-18-10 | A-2 | Added information on ARINC 429 data protocol | Appendix A |
| 2-9-10 | A-3 | Added information on ARINC 429 transmission issues | Appendix B |
| 4-10-10 | B | Updated information on ARINC 429 data protocol | Appendix A |
| 8-30-10 | C | Corrected mistakes in binary-data examples for 0 to 6553 and -32 to 32 scalings | Appendix A |