AEROSYSTEMS

MODERN DATA ACQUISITION SYSTEMS

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Abstract

Modern data acquisition systems are more accurate and capable of higher data rates than ever before. This will be a discussion on the Safran Data Systems network based XMA and MDR hardware that bring modern day accuracy and performance to the flight test community.

Introduction

1. LEGACY COMMUTATION SYSTEMS
2. MODERN DATA ACQUISITION UNITS
3. DATA DISTRIBUTION STANDARDS
4. TELEMETRY
5. DISTRIBUTED SYSTEMS
6. FUTURE OF DATA ACQUISITION UNITS
7. CONCLUSION

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LEGACY COMMUTATION SYSTEMS

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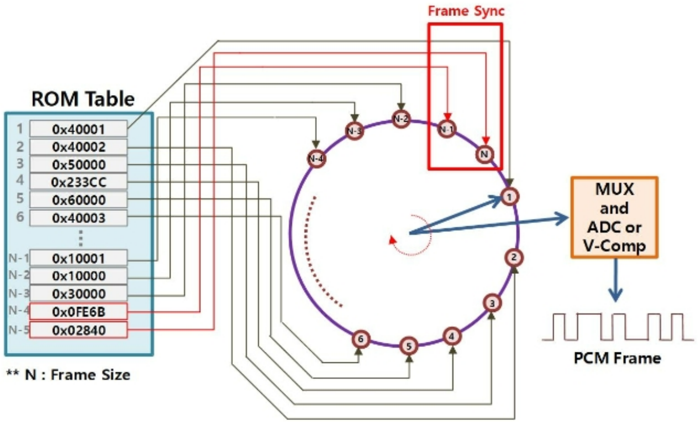

Legacy commutation systems

- PCM data/clock only option
- Sampling schedule based on PCM frame
- Single A/D
- Low bandwidth
- Proprietary I/O and setup formats

Legacy PCM data acquisition units (DAUs) were based on a PCM master clock for system sample schedule. These commutator systems often had a single A/D for acquiring all data channels. This had limitations in system performance. Minimum settle time had to occur between channel sampling for accuracy which impacted over speed of the system. They were often slow with limited bandwidths usually under 5 Mbps. The configuration of these systems was usually proprietary and time consuming to configure. Signal conditioning for channels was a large portion of the end user's responsibility and often external to the DAU itself. These systems were limited to only producing PCM data and clock as an output. Specialized methods and hardware were used for asynchronous data sources. Data recorders were based on mechanical real to real or helical scan mechanism that were limited in what they could perform in harsh environments.

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MODERN DATA ACQUISITION UNITS

Modern Data Acquisition Units

- Simultaneous sampled system
- Phase error between channels is measured in nano seconds
- Generic acquisition modules
- Simultaneously acquire synchronous and asynchronous data
- Advanced bus parsing
  - MIL-STD 1553
  - ARINC 429
  - AFDX
  - Ethernet
  - RS232/422
  - CAN
- On board processing
- External time synchronization
  - IRIG-B
  - GPS
  - PTP

Modern Data Acquisition Units

Modern DAUs have benefited greatly from modern electronics. With advances in miniaturization and speed improvements, we now have small, fast, modular DAUs with integrated signal conditioning that allow for system wide simultaneous sampling of all data channels with high cross channel accuracy. Adding network capability has greatly enhanced the flexibility and capability of the modern DAU. This made distributed systems much more capable, it brought all the features that have been implemented for networking to the modern DAU. System configuration protocols, time protocols, file sharing protocols, the list goes on and on. One of the biggest features for modern DAUs is the ability to take advantage of IEEE-1588 (PTP). Distributed network time protocols allow for large scale system synchronization with nano-second accuracies. You no longer need to run IRIG time to all the acquisition system components. The system can synchronize to a single time source with ease and accuracy. All the acquired data is available for output distribution in many forms. PCM is still being predominantly most used, but Ethernet output now provides a flexible output system that no longer limits the user to PCM.

Modern Data Acquisition Units

Generic analog channel modules allow for reduced number of specialized signal conditioning modules. Many types of transducers can be sampled from a single multi-channel module with complete independence from adjacent channels on the same module. This increases ease of system configuration and allows for more spare channels in a system.

Data sources from synchronous channels (analog) and from asynchronous channels (digital) can be comingled in the same system or even in the same hardware stack for tighter system integration. These digital sources vary greatly in communication types and protocols resulting in increased processing requirements for parsing these data types. MIL-STD 1553, Ethernet, IEEE-1384, AFDX and CAN bus all have specific requirements for filtering and message parsing. This can all be done internally to the DAU.

Modern Data Acquisition Units

In addition to powerful message and data parsers. On board data processing is now often used in place of bulk data streaming. The data can be sampled, processed and analyzed before sending output to the telemetry stream.

Time, the most important aspect of any data acquisition system, has many options for synchronization. GPS, PTP and IRIG are all used for time synchronization. Often one unit will operate as a time master that is synchronized to GPS and then provides time to clients via PTP or NTP. IRIG is still a choice when there is not a clear reception for GPS.

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DATA DISTRIBUTION STANDARDS

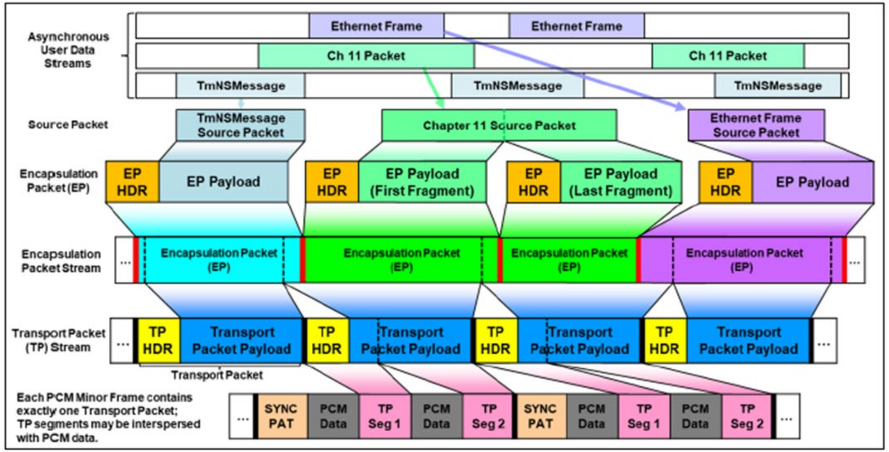

Figure 7-1. Packet Telemetry Overview

Data Distribution Standards

- **Standards based network protocols**
  - CH10
  - TMNS
  - IENA
  - DAR

Data Distribution Standards

All the data, once acquired, needs to be distributed for recording, monitoring and analysis. The options for packaging this data are numerous. The go-to option has historically been PCM which has some significant benefits. PCM offers low latencies of transmission, ensures synchronicity of the data samples and is deterministic in reception. It is an inherently streaming process, which means that each sample is sampled one after another. This makes calculating time for a sample a simple process. The main difficulty with PCM occurs when it is necessary to acquire data that has been previously sampled in a different system and is already in digital form. The data now must be synchronized with the PCM frame format which is often on a different sampling schedule. Often data coming from digital busses is sampled at rates that are not inherently compatible with the PCM sampling schedule.

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Data Distribution Standards

This causes timing issues that must be addressed in order to keep cross channel timing coherent. The external data typically must be over-sampled in order to ensure that all samples are captured. This is an error prone method and requires significant attention to how this data is processed. Over sampling, stale bits and aliasing are problematic when it comes to synchronizing already digitized data with a PCM frame. PCM can be an excellent streaming method for acquiring analog data channels but is difficult to synchronize with other asynchronous digital sources.

Data Distribution Standards

Network formats provide for a standards-based method to overcome some of the issues with PCM as a transport method. Network protocols are more flexible in their ability to stream asynchronous content, but with this flexibility you give up some amount of latency and determinism.

There are several network packet formats that have been standardized in the test and evaluation community. TmNS, CH10 UDP, DAR, IRIG 218, IENA are the main contenders. These have all been in existence in some form for many years now and there is to some degree processing infrastructure in place to handle all of them. They all have their respective pros and cons which we cover. There is no one choice that is best for all applications.

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Data Distribution Standards

TmNS is an open format packet type that relies on meta data definitions in an MDL text file for packet format and measurement definitions. It is from the iNet standards that have since been adopted by the RCC in the IRIG-106 standard. Parsing this packet format requires that you first parse the MDL information in order to understand how to extract and process the measurements from a TmNS packet. This provides the most flexibility in allowing for packaging dissimilar data types into a network packet. This task can be as simple or as complex as needed to support the data encapsulation task. One of the potential issues would be differences in vendor implementations. One vendor can describe a common packet format completely differently from another vendor. This could cause complexities for the MDL parser to ensure that it is robust enough to handle all the differences in vendor implementations.

Data Distribution Standards

The Chapter 10 standard was originally adopted as a multiplexed data file format for data recorders. The packetized nature of Chapter 10 lends itself well to being a network format as well. Chapter 10 UDP (CH10 UDP) is an extension of the IRIG-106 Chapter 10 standard to stream the Chapter 10 packets over a network. Chapter 10 is a well-defined format in that all the packet formats for the different data types are defined in the standard. This type of definition significantly lowers the misinterpretation by implementors for building and parsing the packets and the content. The complete standard is a combination of several IRIG-106 chapters that are used in concert to fully document the specification. These chapters are primarily Chapters 6, 9, 10 and 11. Chapter 11 defines the data channel packets that are used for the encapsulation of the data in the packets.

Data Distribution Standards

Chapter 9 defines the meta data language or file that is used to document data channels and measurement details. This file suffers from the same misinterpretation issues that MDL suffers from. Often different implementations interpret the specification differently leading to errors in parsing and processing.

IENA, DAR, DARv3, among some others are also standards in use in the community for packetizing data on the networks. The many options for sending data on a network underscores the flexibility of using a network for data streaming from DAUs. This allows DAUs to stream data to other systems, data recorders, and telemetry output. There are even units available that will translate between the different packet types to ensure that resulting output is all uniform in format.

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Data Distribution Standards

Because standards-based protocols are in common use among vendors, it is conceivable to have heterogenous data acquisition systems that are not reliant on a single vendor. This allows the user to select “best-in-bread” hardware to maximize his capabilities and use the best tool for the job.

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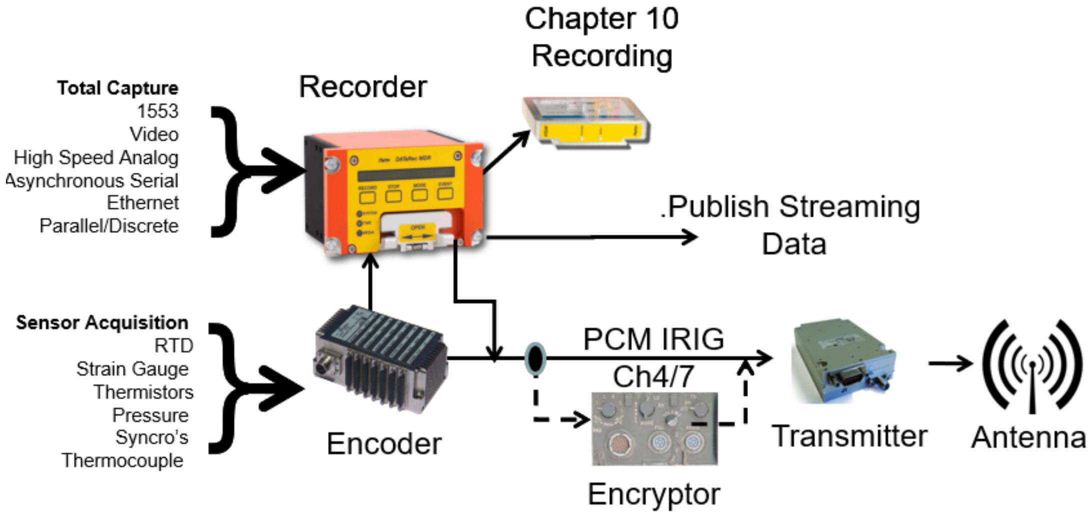
TELEMETRY


Total Capture
1553
Video
High Speed Analog
Asynchronous Serial
Ethernet
Parallel/Discrete
Recorder
Chapter 10
Recording
.Publish Streaming
Data
Sensor Acquisition
RTD
Strain Gauge
Thermistors
Pressure
Syncro's
Thermocouple
Encoder
PCM IRIG
Ch4/7
Encryptor
Transmitter
Antenna

Telemetry

- **CH4 PCM**
- **Packetized Telemetry**
  - iNet / TMNS
  - CH7

Telemetry

One of the main functions of the DAU is to provide an output that is used for a telemetry downlink. There are many formats the telemetry output can take as well. The industry standard method for decades has been IRIG-106 Chapter 4 PCM. There have been several movements to supplement traditional PCM with packetized telemetry. The iNet standard being the most well-known. This standard utilizes a full duplex (bi-directional) link between the test article and the real-time ground station. This allows for the data packets to be streamed in real-time as well as allow for querying of previous data in the event that data had been missed or a “drop out” has occurred. This makes the telemetry link substantially more robust and allows for a more thorough and reliable real-time analysis capability.

Telemetry

The downside to packetized telemetry is that you give up latency and bandwidth efficiency for flexibility. Latency is induced any time that you switch to a packetized method versus a streaming method (PCM). Packetization latency is induced mainly from the amount of time necessary to collect all the data samples that are targeted for a specific packet. This is referred to as packet closeout time. Packet closeout time can be reduced to a minimum to keep latency low, but this will result in increased overhead due to the need to send many packets. Each packet, regardless of type (TmNS, CH10, etc.) has a packet header that identifies the packet and usually a time stamp. This packet header causes overhead because it is not data, it is meta-data that is needed to know how to process the data. The ratio of header information to actual data in the packet is called the packet efficiency. Having a good packet efficiency is ideal to maximize the telemetry bandwidth. We do not want to be utilizing valuable telemetry bandwidth to send meta-data. An efficient packet will have a large amount of payload data relative to the size of the packet header. But as we've already said, the more data you packetize the higher the latency. The goal is to balance packet efficiency with packet latency so that telemetry bandwidth can be maximized with the least amount of latency.

Telemetry

There are often instances where no amount of added latency can be tolerated. In this case the streaming PCM format can still be used. It is important to point out that not any single method is meant as a replacement for another. All the data streaming and packetization methods mentioned are one more tool in the toolbox that can be used. A mix of both streaming formats and packetized formats can be used simultaneously to achieve the ideal balance between latency and flexibility. IRIG-106 Chapter 7 strives to bridge this gap. This streaming protocol offers a mix of both low latency streaming PCM and packetized data in one standard. This mix is an attempt to blend both techniques into a single, standards-based solution that can provide the flexibility of packetized data with low latency data.

Telemetry

Modern DAUs often have support for multiple, simultaneous outputs and the flexibility to select which streaming and/or packetized format to be used. Since no one format or process is ideal for all applications, most DAUs opt to provide many options. This can be troublesome for the development of these products but is necessary to provide the support that the industry requires.

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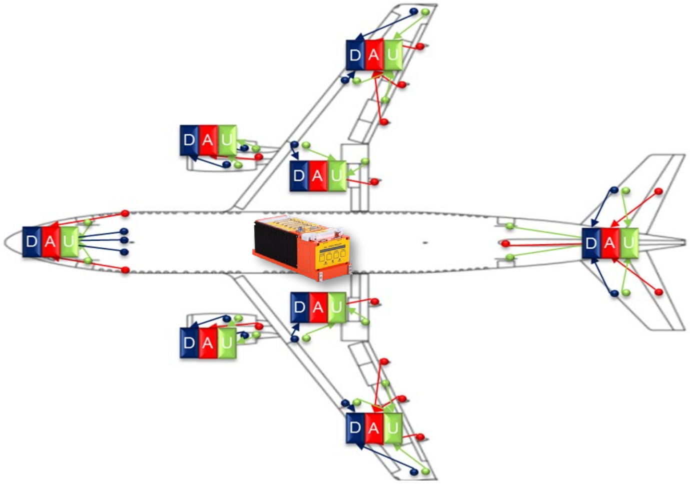
DISTRIBUTED SYSTEMS



Distributed Systems

- **Ease of configuring and loading the system**
  - Ethernet
  - USB
- **Scalability – distributed units**
- **Seamless Recorder-DAU acquisition**
- **Wired or Wireless connections**
- **High accuracy wireless time synchronization**

Distributed Systems

Now that DAUs are network-based devices, they can easily scale to support remote locations in hard-to-reach areas of the test article. It is common to mount one or more remote DAUs and only need to run Ethernet connections back to the main acquisition system. Often a wireless solution is needed, wireless modules can be included in the DAU to facilitate a wireless network connection back to the main acquisition system. Large network distributed systems are possible now with common hardware. Network switches, DAUs and wireless links make for easy to setup, configure and use. High accuracy time synchronization over wireless links has been a challenge. Technologies such as UWB allow for PTP type accuracies over wireless links.

Distributed Systems

Modern DAUs now seamlessly integrate with the data recorder if not act as the data recorder itself. In the case of a chapter 10 data recorder, the DAU can send its data as chapter 10 packets back to the recorder. The recorder can record these packets as native packets in the chapter 10 file as if the recorder itself had receive the data. This provides choices now for where data can be downlinked to the ground. You can downlink the data from the DAU or from the data recorder. If from the data recorder, you no longer will need to connect digital busses to the DAU, only to the data recorder. This frees up the DAU to only focus on analog data. All asynchronous data can be recorded and filtered at the data recorder.

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FUTURE DATA ACQUISITION SYSTEMS

Future Data Acquisition Systems

- **Fiber Optic measurements (Fiber Bragg Grating)**
  - Strain
  - Temperature
- **Higher acquisition speeds**
- **Better accuracies**
- **Larger record capacity**
- **Smaller, lower power units**
- **Quick reaction units**

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CONCLUSION

Conclusion

Flight test programs can now leverage standard networking practices to facilitate large, distributed network-based data acquisition systems to meet fast paced program requirements. Use best in bread hardware and technologies to increase capability and reduce costs and time.

QUESTION?