ADVANTAGES OF GENERAL PURPOSE TELEMETRY DATA AND CONTROL SYSTEMS

John C. Hales
Environmental Test Laboratory
Boeing Aerospace Company
Post Office Box 3999, M.S. 86-12
Seattle, Washington 98124

ABSTRACT

A key milestone for every telemetry design is that date when everyone agrees on a definition of the design requirements. Unfortunately, specifications often become obscured as test constraints change, additional requirements are uncovered, test objectives are more clearly defined, and budgets are cut in half.

Historically, telemetry designs using technology, hardware, and philosophy that pre-date Christopher Columbus have caused obvious rigidity to the system design and its operation. Once completed, program managers become ruefully aware that these systems are difficult (if not impossible) to modify and are always very costly to change.

Telemetry systems available today offer the flexibility necessary to accommodate a frequently changing measurement list. Not only can the measurement list be changed, it can be changed during the course of a test in progress. If requirements expand, hardware may be added. If the test is a non-destructive test, the system can be configured for use on future programs.

Key Words: Programmable, General Purpose, Telemetry, Control, Data Acquisition

INTRODUCTION

Three obstacles, perhaps more than any others, need be overcome before you invest in a PCM system. You must first define the test requirements to a level of detail that will give you a warm feeling that the objectives of the test will be accomplished. You must identify not only these requirements but must also provide for a smattering of not yet defined requirements that are certain to arise after the PCM system has been purchased.

Secondly, hardware must be identified that will comply with the design requirements. Typically a test will have several unique requirements. This usually results in a search for a corresponding unique hardware design. This follows with the dilemma of whether to build the hardware yourself or to search for someone willing and able to build your unique system.

Once the test requirements have been defined and hardware sources found, a battle with budgets and schedules looms on the horizon. Finally, if you don’t overrun your budget to much and finish not to far behind schedule, you might feel easy in claiming to have had a successful test.

If you were to trace the history of telemetry data systems, you would probably find the original system to have been some special purpose design used on a missile test. Today, as costs decline with advancing technology, we see more and more commercial applications for telemetry systems. Here the customer is involved with tests where a telemetry system may be used over and over again. For test situations that are nondestructive, reusable hardware is required.

The intent of this paper is to discuss how programmable, general purpose telemetry hardware can provide solutions to problems that systems of the past could not provide. Test requirements are still the most important facet of test design. For this reason, serious consideration should be given modern hardware in fulfilling those requirements. Hardware available today can provide realtime flexibility in user oriented control and data processing not available in the fixed systems of the past. The advent of new memory techniques and low cost microprocessors have changed the architecture of current PCM system designs to provide this flexibility. Smart systems with a realtime data control link to an operator seated at a ground station terminal can also decrease many time consuming pre-test evaluations and calibrations (1).

LIMITATIONS OF TRADITIONAL TELEMETRY SYSTEMS

A typical telemetry system, as shown in Figure 1, acquires sensor data, and amplifies or conditions this data to be compatible with the sampling circuits. Once the data is sampled and converted to a digital data word, these words are encoded to serial data for transmission to a ground station where they are recorded and processed. Systems of this sort have serious limitations. Several of these limitations are discuss below:

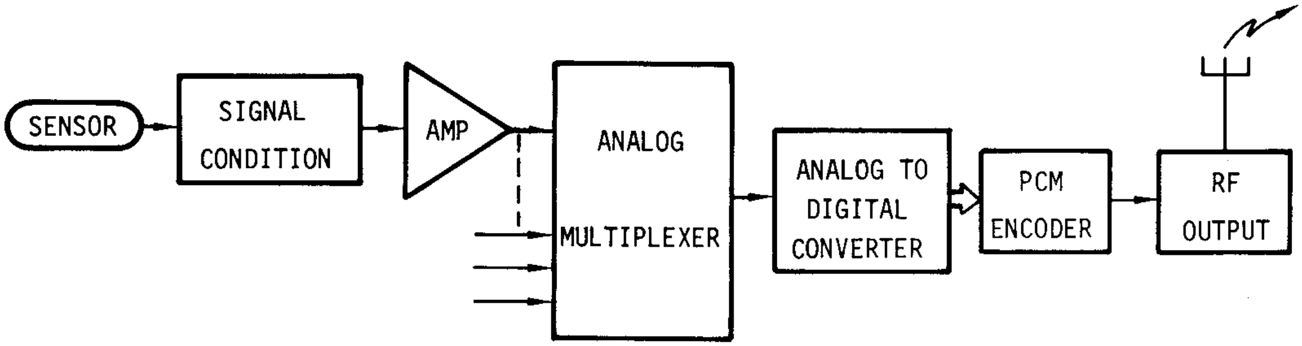

FIGURE 1. STANDARD TELEMETRY SYSTEM

*** Lengthy Calibration Process For Signal Conditioning Circuits**

Perhaps the biggest headache you'll find in preparing for a test is the calibration process of the combined sensor and signal conditioner subsystems. Because the output ranges of the sensors are often unpredictable, it is not uncommon to record a test run to get an idea what adjustments need be made. If frequencies higher than those of interest are disturbing the data of interest, filters are switched in and out until the data looks right. If the signal is riding a large bias, counter voltages or "bucking" voltages are sometimes employed to reduce the bias effect. Gains also need to be adjusted to provide full scale swing of the sensor output. The final outcome should be the proper set of filters for each channel with gains and biases adjusted to provide for a maximum deviation of the sensor output.

*** Difficult to Change Signal Multiplexing Sequence**

PCM formats, as shown in Figure 2, consist of data frames in which samples taken from specific sensor channels are mapped or placed in cyclic order in the PCM serial stream. A series of data frames is much like a series of trains (end to end) where each train has the same number of cars. The engine can be compared to the frame sync indicating the start of each frame of data. Each car represents the location of data acquired from a specific sensor channel. If more than one sample of data is acquired from a single channel during one data frame, the data is said to be supercommutated. Supercommutation is illustrated in Figure 2 in which, for example, channels 2, 4, 6, 8, etc., are samples from a specific sensor. The effect is to give that channel a sampling rate higher than the frame sampling rate. Sensors can also be sampled only every other frame period or less, thereby, giving that channel an effective sampling rate that is less than the frame sampling rate. This technique is called subcommutation and allows several sensors to share the same sampling period of a data frame (2).

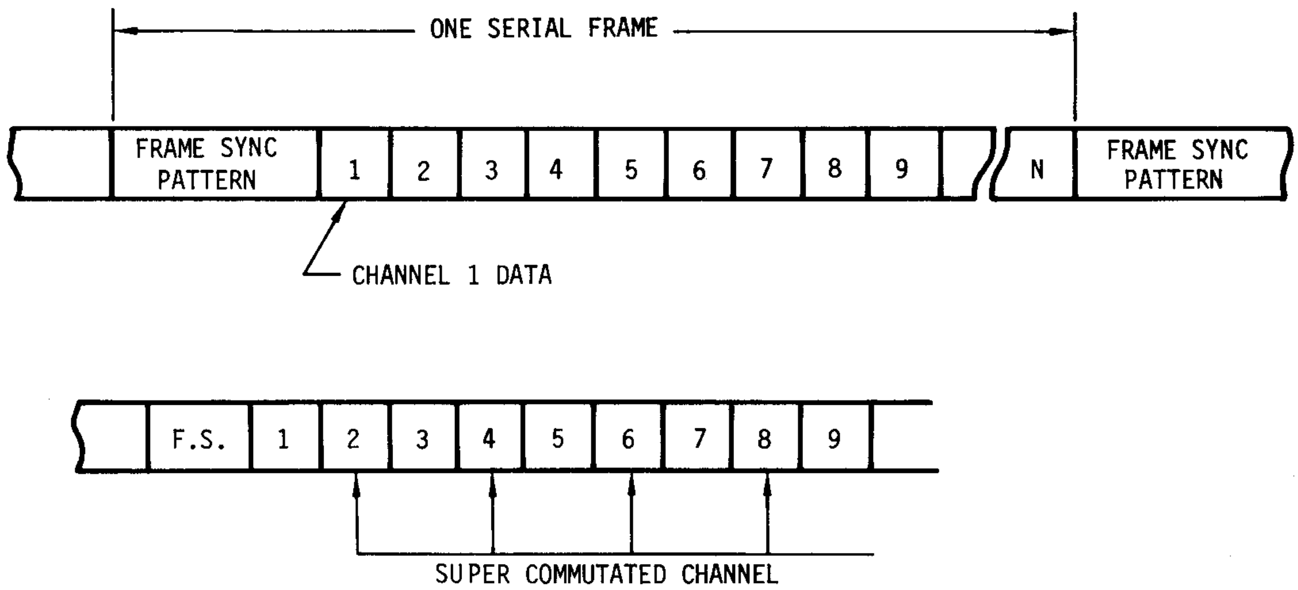

FIGURE 2. PCM DATA FORMATS

Telemetry systems have been very rigid in how data frames were structured. Once the frame was configured, any change required a hardware modification. Today, most PCM data frames can be reconfigured by changing the PCM data cycle map stored in an EPROM. This is usually accomplished by disassembling the PCM encoder, removing an EPROM, erasing its contents, programming the EPROM with the new PCM data cycle map, re-inserting the EPROM in the encoder, and reassembling the encoder. Because of this, you can well understand that EPROMs are physically bothersome to reprogram. You may feel reluctant to change a PCM frame that is "OK" but not perfect.

*** Unalterable Sample Rates**

Anyone who has ever designed a telemetry system has had to determine an optimum sample rate. The sample rate affects other parameters such as serial bit rate and accuracy of the sample. If, for instance, your system cannot operate at sufficiently high bit rates, you may be required to reduce the accuracy of your samples to fewer bits per word thus reducing your output bit rate. Once you determine the optimum configuration of word length, sample rate, and output bit rate, your system takes on the form of the Rock of Gibraltar; immovable, unchangeable,...

*** No System Status Monitor**

In preparation for a test, you may sometimes spend months, even years working out the smallest of details. Then when the test actually occurs, you stand back while the test runs its course, hoping you planned or covered all possible contingencies of the test, and praying that everything works like it did back in the lab. A serious short fall in older PCM telemetry designs is their inability to perform an end-to-end self test and calibration. You'll probably agree that if you had this capability, your confidence in starting a test would be greater as you push the start button that bends a beam, blows a hatch, or fires a missile.

*** Limited System Growth**

Most telemetry systems have had very little (if any) growth capability. If the test engineer counts incorrectly the number of channels to sample, adding these channels later could be costly as you rewire, repackage, and reformat your system. For the company not wanting to start with a large investment in a large system, there is an uncomfortable cost trade: buy a system today that will need to be replaced later or make an estimate of future needs and make the big investment (who knows, maybe the estimate will be good).

ADVANTAGES OF PROGRAMMABLE TELEMETRY SYSTEMS

As you compare the structure of telemetry systems of the past with those being designed today, you will find increased flexibility and capability. Advances in today's systems stem from the incorporation of microprocessor controllers with programmable data and control buses. As shown in Figure 3, all components of the system are tied to control and data buses originating with the microprocessor.

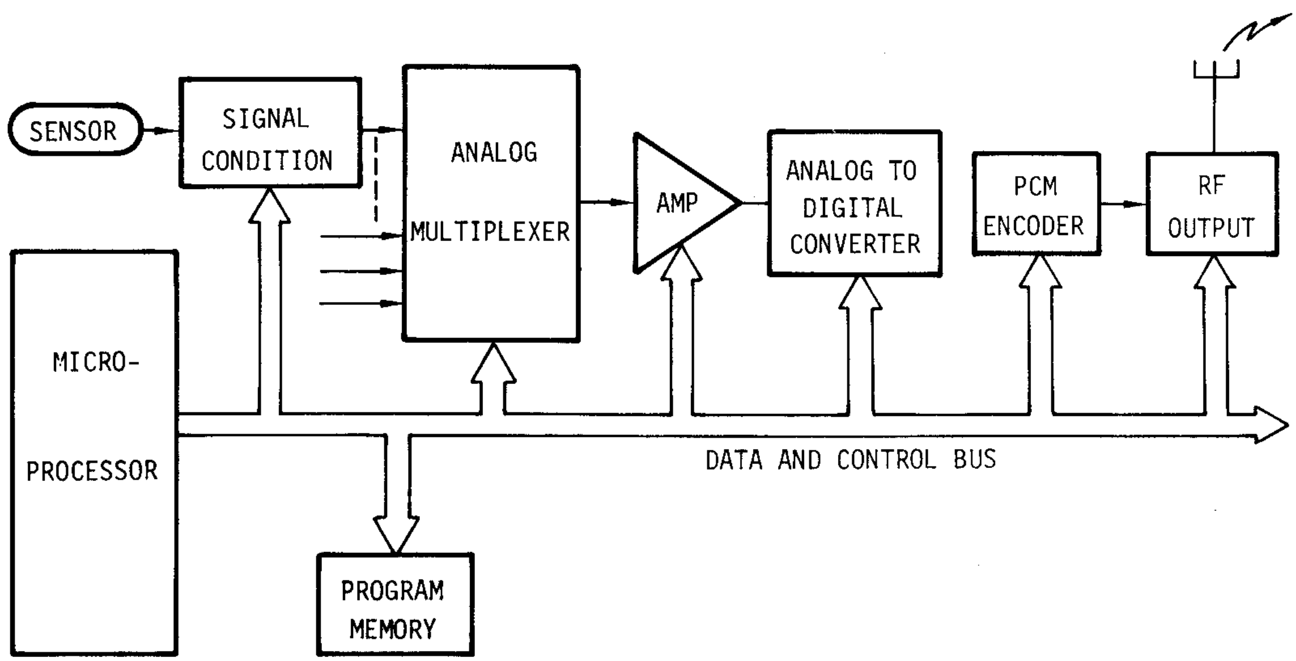

FIGURE 3. PROGRAMMABLE TELEMETRY SYSTEM

A system developed under contract to the Air Force by Northeastern University demonstrates, to a large degree, the flexibility and advantage of a programmable system. This system lacked the ability for operator interaction but as you look at the tremendous versatility offered, as shown in Table I, you will see why their system is used in several applications today (3). Practically every element of a telemetry system, such as this one, can now be tested or calibrated, controlled, and operationally modified either before a test or during the course of the test by the programmable nature of the microprocessor. Table II lists system parameters that lend themselves very well to this concept.

Because of the versatility of programmable data and control buses, modularized components are easily added to a system (4). For instance, Figure 4 shows the addition to the bus of our sample system, discrete input and output modules, an RF receiver, and a programmable clock. The clock module generates timing signals at frequencies programmed to optimize the characteristics of the data gathering capabilities of our system. The receiver provides uplink control from a ground station for tasks such as end-to-end system tests and modification of PCM cycle maps. Digital data modules provide data acquisition from external digital systems. An output discrete module can be programmed for various command tasks enabled during a test.

Modular encoders have been around since 1975 (4). Even these early systems were completely modular such that modules could be assembled in various configurations to meet test requirements. An obvious advantage of modular design is that standard modules can be mass produced thus reducing their cost. The modular concept combined with programmable capabilities of microprocessors offers distinct operational and cost advantages. The following is a discussion of some of these advantages:

*** Software and Real Time Control**

Software is becoming a prominent part of data acquisition systems. The advantages of software control can be seen in most of the required functions of a telemetry system. Requirements for realtime data display and control make it essential that there be a software link between the ground station and data acquisition software in the telemetry system (1). Bi-directional data communication provides system test visibility and control we have all lived too long without.

*** System Reliability**

Concern exists that any interactive control of a telemetry system is subject to faults. Faults may occur because of the unpredictable nature of transmission and reception environments. However, this condition is solved by a variety of standard and relatively simple techniques. Multiple transmissions, parity checks, receive/acknowledge checks,

TABLE I

ENCODER SPECIFICATIONS (3)

Analog Inputs:	Number of single-ended channels is selectable up to 158. Differential channels are selectable up to 8. Word Length is programmable from 8 to 12 bits/word. Gain/Offset per Channel is Programmable.
Digital Inputs:	Number of channels is selectable up to 64. Word length per channel is selectable from 8 to 12 bits.
Outputs:	The following standard IRIG codes are program selectable: NRZ-L, NRZ-M, NRZ-S, BIO-L, BIO-M, BIO-S, DM-M, & DM-S. Bit Rate is programmable from 2 bits/sec to 700k bits/sec.
Output Filter:	Low pass filter is variable from 640 Hz to 700k Hz.
Cycle Map:	Any channel may be supercommutated. Any channel may be subcommutated. Maximum number of minor frames to major frame is 256. Order of channel selection completely programmable.
Frame Sync:	Frame synchronization may operate using anyone of the following modes: ID Mode, Pattern Mode, or Complimentary Mode.

TABLE II

PROGRAMMABLE SYSTEM PARAMETERS OF TODAYS TELEMETRY SYSTEM

- Signal Conditioners
  - Input Filters
  - Built-In-Test
  - Self Calibration
- Analog Multiplexer
  - Frame Cycle Mapping
  - Modify Frame Size
  - Number of Channels
- Analog to Digital Converter
- Analog Amplifier
  - Offset and Gain
  - One Amplifier for the whole system
- Microprocessor
  - Upload Commands
  - Future Programmability
  - System Monitor
  - Built-In-Test

Accuracy of Samples
(number of Bits/Word)
Sampling Rates
Clock Frequency of ADC

PCM Encoder
- Type of Output PCM code
- Type of Synchronization Codes
- Output Filter

Alarm Generation
Dynamic switching of
Frame maps correspond
to Event Timing

RF Transmitter/Receiver
Center Frequency

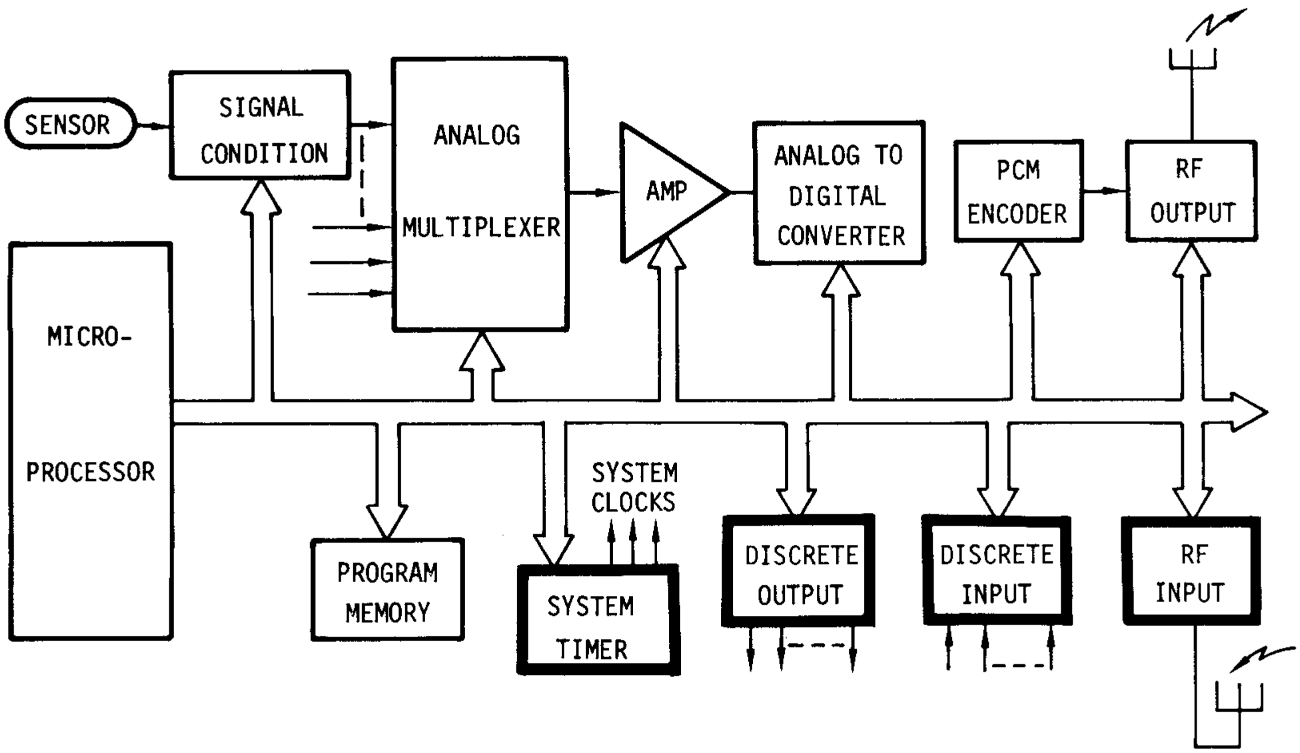

FIGURE 4. BUS ORIENTED GROWTH

memory map checks, and built-in-tests all provide system checks which can be used to maintain a log of status throughout a test. Indeed, the advantages and self test features available make today’s telemetry system more reliable than those of yesteryear.

*** Automatic Sensor Calibration**

The advantages of software control are evidenced here as much as anywhere. Programmable PCM encoders with integral signal conditioning have only recently became available. Signal conditioners of this type are available for resistive temperature devices (RTD’s), strain gages, and thermocouples. Attenuators, pulse counters, filters, AC/DC converters, serial and parallel digital interfaces are also available. One manufacturer alone has sold over 1000 such systems (5).

* Ground Station Control of Sampling Maps

Using an uplink, the ability now exists to quickly and easily load and test different sampling maps during pretest sensor calibration and during the actual test. This capability opens up new techniques for sensor calibration and data acquisition. If a sensor requires a high sample rate during a specific time interval, the sample map may be changed during that time period to concentrate on the critical data channels. This technique keeps the frequency and channel count to a minimum.

Setup time is reduced and accuracy and confidence of the acquired sensor data is increased. This is achieved by multiplexing in-circuit calibration tests into the PCM data sent to the ground station. The processed calibration data is thus used during a test as a sensor monitor. This automatic calibration process will tend to minimize errors introduced by manual entry of Cal data into the ground system computer. Actual calibration data is thus used rather than projected or calculated data (1). If a channel does not have the proper gain and if frequencies not of interest are interfering, filters can be changed and gains adjusted by realtime monitoring and correction from an operator seated at a ground station terminal.

* Software Controlled Multiplexer

The Analog multiplexer (MUX) can be programmed for super-or sub-commutated channels. This allows the sample rate for any given channel to be modified under software control. If you care to view a particular channel with greater accuracy, you simply super-commutate that channel and the effective sample rate increases. As input signals are received from input sensors, the MUX can also adjust for single or differential operation (6).

* Programmable Gain Amplifier

The multiplexed analog data, in the sequence requested by the microprocessor is amplified by a programmable amplifier. Here, because of the programmable nature of the amplifier, only one amplifier is needed instead of one for each analog channel. As with the signal conditioners, its offset and gain, for each channel, are controlled as instructed by the microprocessor.

CONCLUSION

Programmable, modular hardware is, by nature, general purpose. Programmable modules offer flexibility and system growth. Overall system reliability is enhanced by the self-test and calibration features offered. System integration and checkout will be easier than with non-programmable systems. User design and development time is significantly reduced by the utilization of standard modules. Changes in the system configuration can be accommodated without significant hardware redesign or repackaging.

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