A VERSATILE MEMORY CONTROLLED PCM ENCODER FOR ADAPTIVE TELEMETRY SYSTEMS*

C. S. JOHNSON
Sandia Laboratories
Albuquerque, New Mexico.

Summary An Adaptive Telemetry System is defined as a flexible, controllable pulse code modulation (PCM) telemetry system which offers many options and many modes of operation prior to and during actual test of a monitored system. The concept of having a telemetry system adapt to the data and circumstances of the test is not new. Large data-gathering systems using computers for control have pioneered this concept. However, the present development activity has centered on a small aerospace memory controlled PCM encoder which can function as the keystone of an adaptive telemetry system. The encoder can be used by itself as a general-purpose airborne encoder.

Introduction The flexibility and adaptability of the encoder are made possible by recent developments in the solid-state memory field, particularly the metal oxide field-effect-transistor read-only-memory (MOSFET ROM). The encoder is designed to use a nonvolatile solid-state ROM that is programmed by a special mask at the time of manufacture. The semiconductor memory controls the format of the encoder and may contain more than one format. The encoder has been designed to meet the requirements of general field-test programs at Sandia Laboratories and eliminate the nonrecurring costs and efforts required to develop an encoder with a particular fixed format. (It is being manufactured for Sandia Laboratories by the Dynatronics Operation of General Dynamics and has been designated the MPS-101 encoder.) The encoder, for example, will during a missile flight change formats upon the application of a new digital word to the format control lines. It also has options which permit switching of bit rates and changing to external transmitter premodulation filters to permit either the increase or decrease of data flow from the encoder. These options are accomplished via logic signals sent from external controlling circuits.

The 48 cu in encoder has 64 high-level (0 to 5 volts) and 16 low-level differential (0 to 40 mv) or optionally used as high-level (0 to 5 volts) analog channels. The encoder also has the capability of transmitting up to 64 bi-level channels. The logic of the encoder has been designed so that, if desired, the package may be expanded to handle a maximum of

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128 high-level channels, 128 bi-level channels, and 32 low-level/high-level differential channels. The encoder can encode the input signal into either 6 or 8 bit words at rates up to 750 kilobits. The PCM output can be either NRZ-L or Bi-ϕ-L.

The read-only-memory controls and selects the number of high-level, low-level, and bi-level inputs that are utilized in the PCM output. The memory controls the time multiplex sequence of the input channels. Channels may be supercommutated, subcommutated, or sub-subcommutated by the instructions that are programmed into the memory. The bi-level channels are organized in the encoder on a word basis (6 or 8 channels per word). The memory also contains the frame synchronization code which is used to signify the start of each main frame.

The encoder has been so designed that a number of the functions can be either selected preflight or selected during flight by external logic. The number of data bits and the use of parity for all words in a given format are controlled by signals sent into the encoder via the programming plug. The bit rate is selected by a component change inside the encoder. However, it is possible to take the internal clock frequency from the encoder, divide it externally by an integer number, and reinsert it into the encoder via the overriding external clock input. The determination whether differential data channels will operate in a low-level or high-level mode is a preflight hardwire change.

Considerations for Adaptive TM Systems Much of the information transmitted on a telemetry link is usually summarized within predetermined design limits. If the telemetry system could observe the data and know that it is within the design limits as required for the system, it would be possible to transmit some signal indicating that all systems are okay. It is generally agreed that a simple okay would probably not satisfy most users because they would ask the question, “Is the telemetry system okay?” Another adaptive approach is the possibility of implementing a flexible PCM system which would sample each channel and decide if there was any data present that should be transmitted and if so, transmit it. If there was not any data to be transmitted, that channel would be skipped. This would be a form of data compression and adaptability. However, the data reduction would be complicated by having to decipher this system even if each channel had an address. Besides the data reduction problem, the additional channel addresses would require additional bandwidth and make this approach to an adaptive data compres sion system undesirable.

The approach chosen as being most reasonable and yet still extremely flexible centers around the capability of the PCM encoder to store and switch to more than one format. The encoder has a capability of using two solid-state 256-word by 12-bit memories that can store up to six average PCM formats. The term “average format” is quite nebulous. To better define this term a sample of an “average format” is shown in Figure 1. This format roughly has the same capacity as a proportional bandwidth FM package which has for a number of years been the standard of the TM industry. This format requires only 75 memory addresses to program. Thus the memory of the encoder that contains 512 addresses would hold 6 of these formats with a few addresses to spare. The channels can be repeated in different patterns from format to format or be completely different sets in each format.

A capability to switch formats in the encoder implies that the ground station must be able to recognize when a change of formats is about to occur. Otherwise, the ground decommutators will be completely mystified by what is going on in the encoder. So format switching necessitates a system of format codes and a word in the format called the format identification. When switching formats in the encoder, it must be recognized that the ground station cannot instantly follow what is being done in the air, so some time must be provided for the ground station to prepare to switch in sync with the encoder. The ground equipment must also discriminate against a format ID word being altered by a noise burst by checking that it has received a valid format ID word. The check is accomplished by programming the first 3 bits of a word to binarily indicate any one of 8 different formats and re-encoding the same 3 bits in the second part of the word so that a check can be performed to determine that the first half of the word is like the second half of the word. If the two 3-bit words agree, then the format word is accepted as being valid.

The next problem the ground station must wrestle with is the time that the airborne system intends to switch. This can be determined by a combination of the format ID and the subcom ID words. The encoder sends out a signal which could be called a busy signal during the last main frame of a sub-frame as a signal to inhibit the incoming change of address. The busy signal will not permit a command to switch formats to take place during that last main frame. A command to change will be seen and entered only at a time when the busy line returns to normal, thus making sure that the format ID word is seen for one whole sub-frame. Since the encoder treats single main frames as groups of two, this feature also insures that even if the format consists of a single main frame it will appear for a total of two main frames. The ground station can therefore detect the presence of the format ID word as being different and prepare whenever the last subcom ID word appears to switch formats at the beginning of the next sync word which would coincide with the airborne encoder’s switch to a new format and possibly a new synchronization pattern.

Philosophy of Adaptive Programmable TM Systems In the development of weapons and missile systems it is not always possible to determine the total performance of the system before several tests have occurred. In this day of expensive hardware, fewer tests, and smaller budgets, every test should yield the maximum amount of information available. Test data is sometimes deleted because there is a lack of telemetry channels and because it is reasoned that other data is more important. During an actual flight it has many times, turned out that the deleted data was the most important. If the telemetry system monitoring the transducers, or fuze or control system, etc., could be made to always optimally transmit the most active channels or the most important data channels as decided against the best a priori constraints, then the telemetry system would be operating at close to maximum efficiency.

To achieve this maximum efficiency the PCM encoder would be switched by a controller (see Figure 2) to a different section of its memory and therefore to a different format to pick up unused but available data channels. For example, an external timer could initiate a format change. During the initial phases of a missile trajectory there are usually very few fuze functions that require monitoring, but a large amount of environmental data must be transmitted. The lift-off format would transmit supercommutated environmental channels perhaps at a higher bit rate. Fuze data could be monitored at very low sample rates, subcommutated into the initial format. After completion of the early phases of the flight, a timer would simply switch to another format and/or bit rate which would transmit fuzing and flight information.

Bit rates can be changed in flight by overriding the internal clock via the external clock input. At the same time, the internal transmitter premodulation filter can be removed from the circuit and the signal routed out to an external premodulation filter before being returned to the encoder for final amplification. When bit-rate changes occur, there willbe a loss of data momentarily on the ground until a second bit synchronizer can acquire the new bit rate.

The switchable bit rate and format change can be teamed together to store a reasonable amount of information at low sample rates in a temporary external data storage device, such as a long shift register. At the end of the storage time, shift register output could be dumped at a high bit rate or interwoven into the PCM bit stream via the serial digital input available on the encoder.

Another example of the utilization of an encoder controller would be the case of employing some external transducer to sense an abnormal condition that might occur during flight and to order the encoder to look at selected channels related to this malfunction., One possible type of malfunction sensor is a gyro which could be used to indicate tumbling of the flight vehicle.

The fuze and flight controllers are other sources of malfunctions. In these cases, the designer would like to know what components had failed and in what sequence the malfunction had occurred. To accomplish this type of diagnosis an external data recognition analyzer would monitor many test points and determine if the proper sequence was occurring. If the nontransmitted data was within the constraints programmed into the memory of the data analyzer, then no other action would be taken to transmit these additional test points. However, if a malfunction was recognized the analyzer could switch encoder formats to maximize the number of test points being transmitted to the ground.

One problem which must also be handled is the fact that the encoder could receive conflicting format commands. This problem is solved by implementing a priority switching arrangement in which every command to switch formats is weighted in a priority scheme. The most important malfunctions related to a given format would be given the highest priority. Generally the initial format would be assigned the lowest priority, thus allowing the adaptive TM system to override the initial format and switch to other formats. If no other commands were received, the initial format would always control.

Format Switching When the encoder receives a command to switch in the form of a new memory address, it will receive this address and load it into a memory address register. At the end of the next minor frame the memory will recycle and reset itself to the new memory address. Control logic starts this format sequence as any other by pulling the sync code from the memory and placing it into the output shift register. The internal memory advance counter steps the memory through the various addresses which are then interpreted by control logic to determine the particular channel addresses that are required in the format. When the channel address of an analog channel comes up the information will be passed out to open the selected analog multiplexer gates. The MOS FET gates will be opened and the input voltage of the data channel will be fed to an analog-to-digital converter. The output of the analog-to-digital converter is then placed in the outgoing PCM bit stream. When the memory sends out an instruction that is interpreted as a bi-level channel address, the bi-level channels will be fed directly into the output shift register. Once the memory has cycled through a complete main frame series of addresses, it will go again to the programmed address and repeat the cycle. Subcommutation is accomplished through mask routines performed by the control logic. The encoder can derive new addresses and jump to them while holding the memory counter at its initial address.

Conclusion The encoder as described in this paper forms the keystone for complex, adaptive telemetry systems to improve the flow of data over RF links from missiles and aircraft. The encoder’s flexibility is due to the logic control and memory system. Its small volume and versatility make it suitable for a large number of applications.

Main Frame

Word No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sub Com. No. 1	Sy	Sy	Sy	LL 1	HL 13	LL 2	HL 14	LL 3	SC ID	BL W1	BL W2	LL 1	HL 13	LL 2	HL 14	LL 3	HL 15	LL 4	HL 16	LL 1
2																				
3																				
4																				
5																				
6																				
7																				
8																				

Word No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Sub Com. No. 1	HL 13	LL 2	HL 14	LL 3	HL 17	LL 5	HL 18	LL 1	HL 13	LL 2	HL 14	LL 3	HL 22	BL W5	HL 30	LL 1	HL 13	LL 2	HL 14
2							HL 19						HL 23	LL 6	HL 31				
3							HL 20						HL 24	BL W6	HL 32				
4							HL 21						HL 25	LL 7	HL 33				
5													HL 26	BL W7	HL 34				
6													HL 27	LL 8	HL 35				
7													HL 28	BL W8	HL 36				
8													HL 29	LL 9	HL 37				

No. of Channels	Type	SPS	Freq. Response
3	Low Level	5000	1000 Hz
2	High Level	5000	1000 Hz
3	High Level	1000	200 Hz
2	Low Level	1000	200 Hz
12 (2 Words)	Bi-Level	1000	200 Hz
4	High Level	250	50 Hz
16	High Level	125	25 Hz
4	Low Level	125	25 Hz
24 (4 Words)	Bi-Level	125	25 Hz

40 Words/Main Frame
6 Bits/Word
240 Bits/Main Frame
1000 Main Frames/Sec.
240 Kilobits/Sec.

Figure 1. Average PCM Format. Requires 75 Memory Addresses

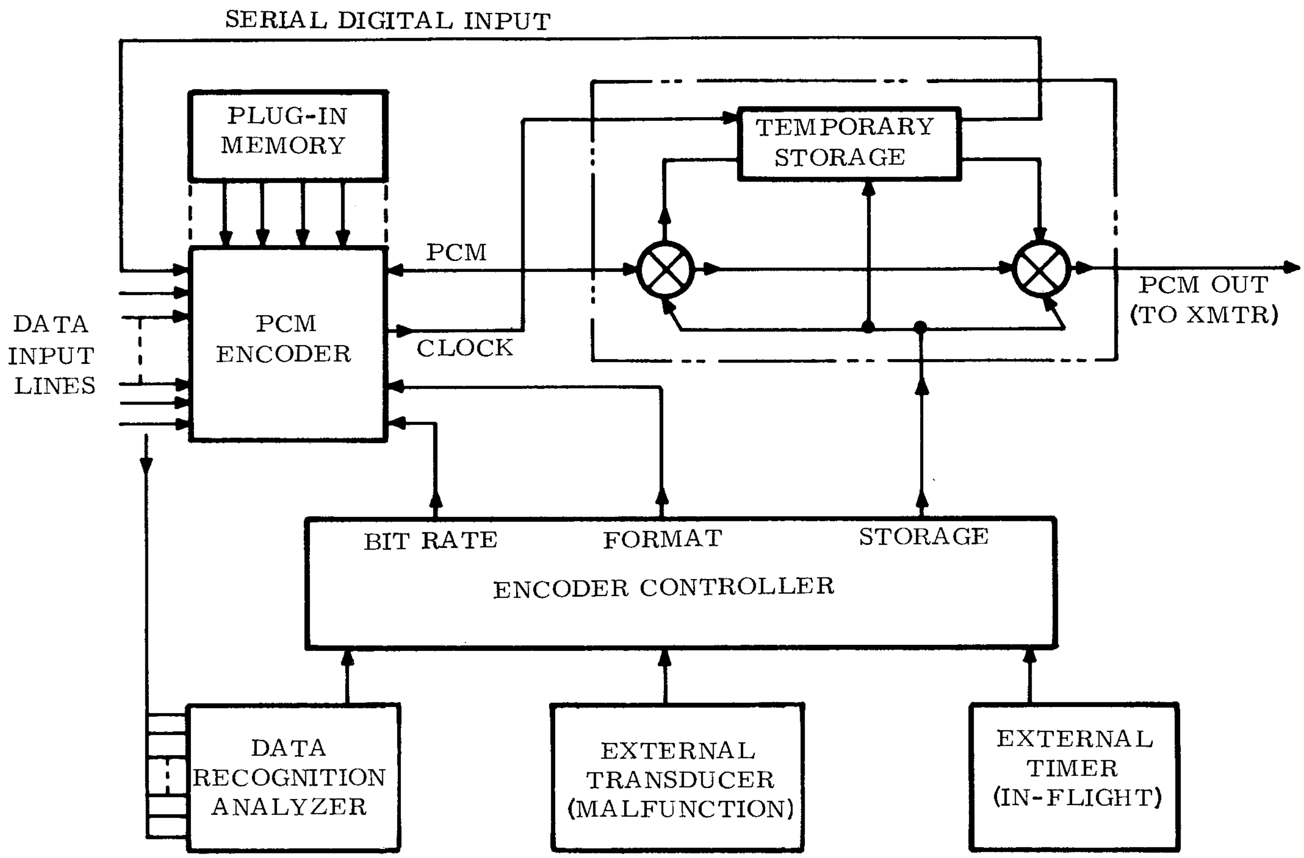

Figure 2. Real-Time Inflight Adaptive PCM System