A PCM-TELEMETRY SYSTEM FOR SOUNDING ROCKET PAYLOADS

R. HOMMEL
Institut für Satellitenelektronik of the Deutsche Versuchsanstalt für Luft- und Raumfahrt e.V., Oberpfaffenhofen.

Summary Complex sounding rocket payloads require on-board data processing and channel capacity which frequently exceed the capability of the standard FM-FM-telemetry system. To obtain the full benefit of the accuracy and information density of sounding rocket experiments a PCM-telemetry system has been developed which provides sufficient flexibility in the choice of channel number, bit rate, time resolution, and accuracy. A first version with Bo channels for scientific data, and 62 channels for technical data will be flown on board of five Black Brants from the Esrange in Kiruna.

Introduction A versatile PCM-telemetry system for sounding rocket payloads has been designed and developed by the Institut für Satellitenelektronik of the Deutsche Versuchsanstalt für Luft- und Raumfahrt, Oberpfaffenhofen, together with AEG-Telefunken, Ulm, to overcome the restrictions in on-board data handling imposed by the standard FM-FM-telemetry system. The general design philosophy was to provide maximum flexibility, and ease of individual adaption to the various requirements of a payload.

Special features of this telemetry unit are pulse height analysis and analog data measurements with an accuracy up to 12 bit. Except of a few special subunits the system is manufactured completely in micro-electronic technique.

In the following the basic system is described as well as the special design for five Black Brant payloads which will be flown in the polar light zone within the scope of the German-American project AZUR.

System Description The telemetry system consists of a few basic functional blocks with compatible interfaces (fig.1):

a) Analog Multiplexers: The multiplexer unit contains 4 or 16 FET-switches, the appropriate control gates, and decoding elements together with inhibit lines providing the possibility to combine up to 64 parallel channels which are controlled by only 6

binary lines. If more than 64 analog channels should be multiplexed several slave multiplexers can be connected by a master multiplexer without deteriorating the accuracy of the multiplexed signal.

b) Analog-Digital-Converters: A series of analog-digital-converters offers 6.8,1o, or 12 bit resolution for the conversion of the small cases (length 29 mm, height 3 mm, depth 15 mm, weight 5 g) , and operates in the successive approximation mode with a clock frequency of 5o kc at a power consumption of 4oo mw. A 14-bit-ADC of the same physical dimensions is also available with a maximum clock frequency of 15 kc, and a power consumption of 7oo mw. To the 14-bit version a correction table has to be applied to obtain the full precision.

The analog-digital-converters (with the exception of the 14-bit ADC) can be supplemented by a sample-hold-circuit having an aperture time of 4/usec at a signal source impedance below 1 kΩ.

c) Count-Shift-Registers: A number of sounding rocket particle detection experiments send statistical pulses to the telemetry unit in order to measure the number of pulses during a given time interval. Generally these pulses are counted in binary counters. At the end of the time interval the information is transferred in parallel form to a central shift register, and there converted into serial form. The binary counter is then reset, and another counting cycle started. Since each stage of the shift register, however, has to be connected to the gates multiplexing the counters a large number of lines running from the counters to the shift register would be necessary significantly impairing the flexibility of the system. The other method to add a separate shift register to each counter increases power consumption and weight of the whole system.

A new approach to the parallel to serial conversion is the use of count-shift-registers which results in a considerable simplification of the logic circuitry.[1] Only the clock pulses and the appropriate word pulses have to be provided for the operation of count-shift-registers. During the readout of the information “zeros” are shifted into the registers; therefore, the registers are automatically reset at the beginning of each counting period. Without any change of the logic concept of the telemetry system count-shift-registers can be added or omitted within the scope given by the maximum number of words per frame. similarly to the insertion of more or less VCO’s in a FM-FM-telemetry system according to the specific volume of data to be transmitted.

Arbitrary register lengths can be composed from individual count-shift-flip-flops available in thick film technique. Nominal register length, however, is 12 flip-flops

[1] Ph. HARTL, R. HOMMEL, H. LIEBELT, and E. TRIENDL, “Possibilities of PCM-Encoding”, Proc. of the ITC, 1967

which are contained in one small package (length 29 mm. height 13 mm, depth 23 mm). The power consumption per bit is about 1 mw.

d) Pulse Height Analyzers: The measurement of pulse amplitudes is frequently required by particle detection experiments. Therefore, it was felt that the incorporation of a pulse height analyzer into the telemetry system would be of value since it allows a simplification of the electronics of the experiments, and increases the information density during the relatively short flight of a sounding rocket. Fig. 3 shows the block diagram of the pulse height analyzer. The analog multiplexer scans the experiment channels which should be analyzed. The inhibit circuit prevents pulses arriving in the hold circuit as long as the digitizing process of the preceding pulse continues. In the h6ld-circuit the pulse amplitude is stored, and held to a constant level for the analog-digital-conversion.

The conversion is performed by a high-speed ADC operating in the successive approximation mode with a clock frequency of 2.5 Mc. The parallel bit pattern generated by the ADC corresponds to a certain pulse amplitude level and addresses the corresponding counter through an 1 of 64 (32,16)-decoder. The content of the selected counter is then increased by “1”.

Since the amplitude analyzing process should be performed during exactly the same time for all amplitude values, whilst the read out command sequentially scans the counters, all counters must be buffered. The buffer accepts simultaneously the information of all counters, and sends it one after another to the output logic of the telemetry system.

The pulse height analyzer can accept pulses of amplitudes between 0 and 5.12 v, pulse widths of at least 2oo nsec, and of a shape typical for the output of charge sensitive amplifiers (fig. 3a). The pulses have to be spaced at least 4/usec apart (3/usec for the 4-bit version); this time is required to store the pulse in the hold circuit, to digitize its amplitude, and to clear the ADC by the output buffer. Therefore, theoretically up to 25o.ooo pulses could be analyzed in one second.

e) Programmer, Subfram Programmer, and Output Logic: The programmer contains the crystal controlled clock generator, the bit-per-word-counter, the words per frame counter, and the necessary decoding elements for the generation of the word pulses for the count-shift-registers. Standard word length is 12 bit, standard frame length 32,64,128, and 256 words. For-subcommutation a frames-per-subframe-counter is contained in the subframe programmer. The output logic provides the synchronization words and converts the NRZ-signal of the ADC, and count-shift-registers into the desired output code.

Technology Wherever possible, monolithic or thick film technique or a combination of both has been utilized throughout the system. The only departure from this guideline was made in submodules which contain a low number of components only, and where the use of micro electronics would have been exceedingly expensive or would have caused technical disadvantages. A benefit of the combined monolithic-thick film technique is the reduction in weight and volume, because integrated circuits and transistors can be mounted in unencapsulated form, and increased reliability, because the mechanical rigidity of the ceramic plate and the thick film network is superior to a conventional construction with discrete elements. The speed of the circuit is improved since connections between individual elements are extremely short and uncontrolled capacities are considerably reduced.

The use of thick-film technique has the obvious advantages over the pure monolithic technique that a basic circuit can be easily modified to fit individual application requirements, p.e. the analog-digital-converters can use the same layout for the 6,8,lo,12 or 14 bit version. Another reason for the application of thick-film-technique is the facts that in a few cases integrated circuits with the special properties required by a specific application are not available on the market or do not have the optimal relation between power consumption, and speed which can be achieved by thick-film-technique since passive elements, and high value resistances can be easily realized with high accuracy.

With the exception of some linear microcircuits the semiconductor elements of the microwatt series of AEG-Telefunken are used in the telemetry system.

System Design for the Polar Light Zone Sounding Rocket Payloads: Eight experiments (proton, electron, alpha detectors, photometer, EUV-monochromator, UV-spectrometer, proton magnetometer, search coil) require the following telemetry channels:

a) 62 technical analog channels, sampling rate 3/sec, resolution 8 bit
b) 7 scientific analog channels, sampling rate loo/sec, resolution 8 bit
c) 1 scientific analog channel, sampling rate 5o/sec, resolution 12 bit
d) 37 pulse rate measurement channels, sampling rate 5o/sec, resolution 8 bit, maximal pulse rate 2-1o^5/sec
e) 12 parallel digital data channels (encoder positions etc), sampling rate 5o/sec
f) 3 pulse height analysis channels, sampling rate 5o/sec, resolution 48 amplitude values
g) Interface for single event pulse height analysis
h) Interface for proton magnetometer signal processing.

The requirements a) to f) can be satisfied with the functional blocks described in the previous chapter (fig. 4). Special arrangements must be made for the interfaces.

The first interface is provided for a single experiment channel which Rust continuously be connected to a 4-bit pulse height analyzer. Moreover, for each analyzed pulse a 2-bit logic configuration information (coincidence-anticoincidence of several detectors) has to be added to the amplitude bit pattern. Since the pulse rate is below 1oo/sec, it was determined to directly transmit the amplitude, and logic configuration pattern of each single pulse instead of counting the number of pulses in the various amplitude gaps as it is done in the normal pulse height analyzer.

A second interface was needed for the output signal processing of a proton magnetometer. During the first period which takes about 2 seconds the magnetometer signal represents a damped oscillation with a frequency between 1.8 kc and 2.2 kc. This frequency has to be measured with an accuracy of o.1 Hz since it is directly related to the total magnetic intensity. The frequency, however, need not to be constant over this period; therefore the interval has to be broken up into several smaller intervals in order to get the fine structure of the frequency curve.

During the second period the coil of the magnetometer is loaded which takes about o.5 sec. During this break the buffer containing the frequency data is addressed by the programmer, and read out to the output logic unit.

The total amount of data to be telemetered results in a bit rate of 8o kc, and a frame rate of 5o/sec. The frame length is 128 words, the word length is 12 bit. The total weight of the telemetry system including RFI control and RFI input filters is about lo kg, the total power drain lo w. The physical dimensions correspond to a cylinder of the diameter of the Black Brant and a height of 12 cm.

In summary, the telemetry system provides the necessary accuracy and channel capacity of complicated sounding rocket payloads. It is capable to interface with a variety of data sources. The ease of analog and digital channel capacity expansion as well as the possibility of pulse height analysis provide a maximum flexibility and versatility which may help to solve telemetring problems for sounding rocket experiments.

This paper presents the results of one phase of research carried out at DVL under cantract WRK 161, sponsored by the “Bundesministerium für wissenschaftliche Forschung”.

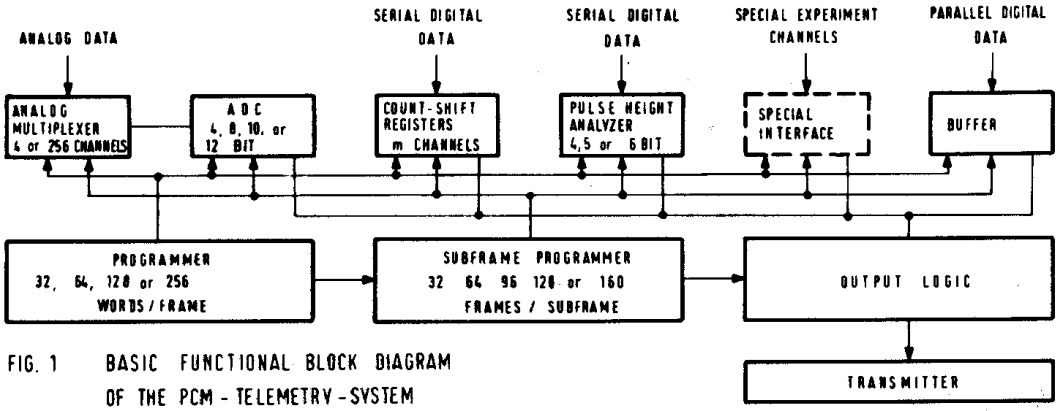
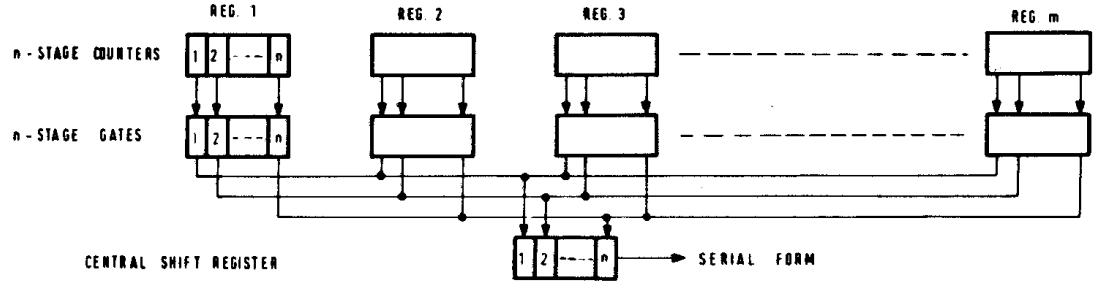
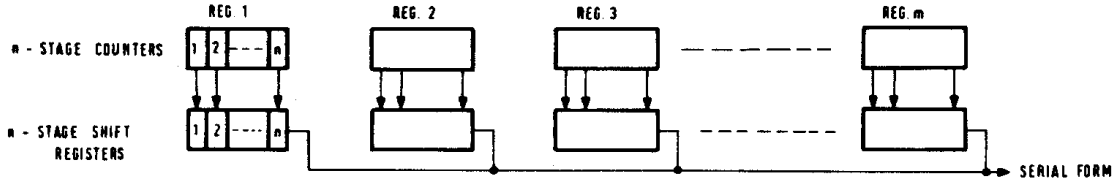


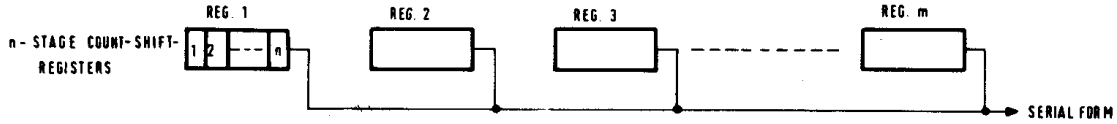
FIG. 1 BASIC FUNCTIONAL BLOCK DIAGRAM OF THE PCM - TELEMETRY - SYSTEM



a) PARALLEL - SERIAL - CONVERSION WITH CENTRAL SHIFT REGISTERS

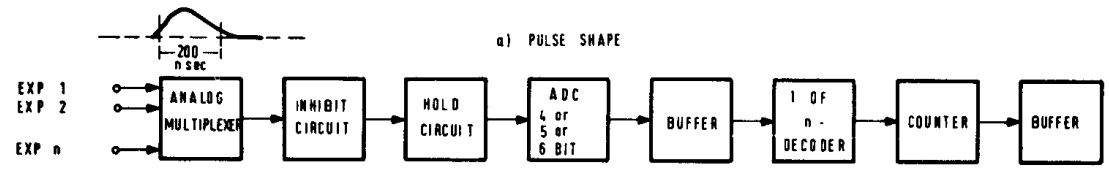


b) PARALLEL - SERIAL - CONVERSION WITH INDIVIDUAL SHIFT REGISTERS



c) PARALLEL - SERIAL - CONVERSION WITH COUT - SHIFT - REGISTERS

FIG. 2 METHODS OF PARALLEL - TO - SERIAL - CONVERSION



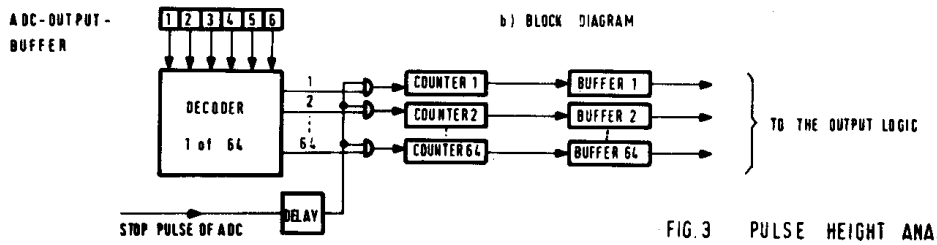


FIG. 3 PULSE HEIGHT ANALYZER

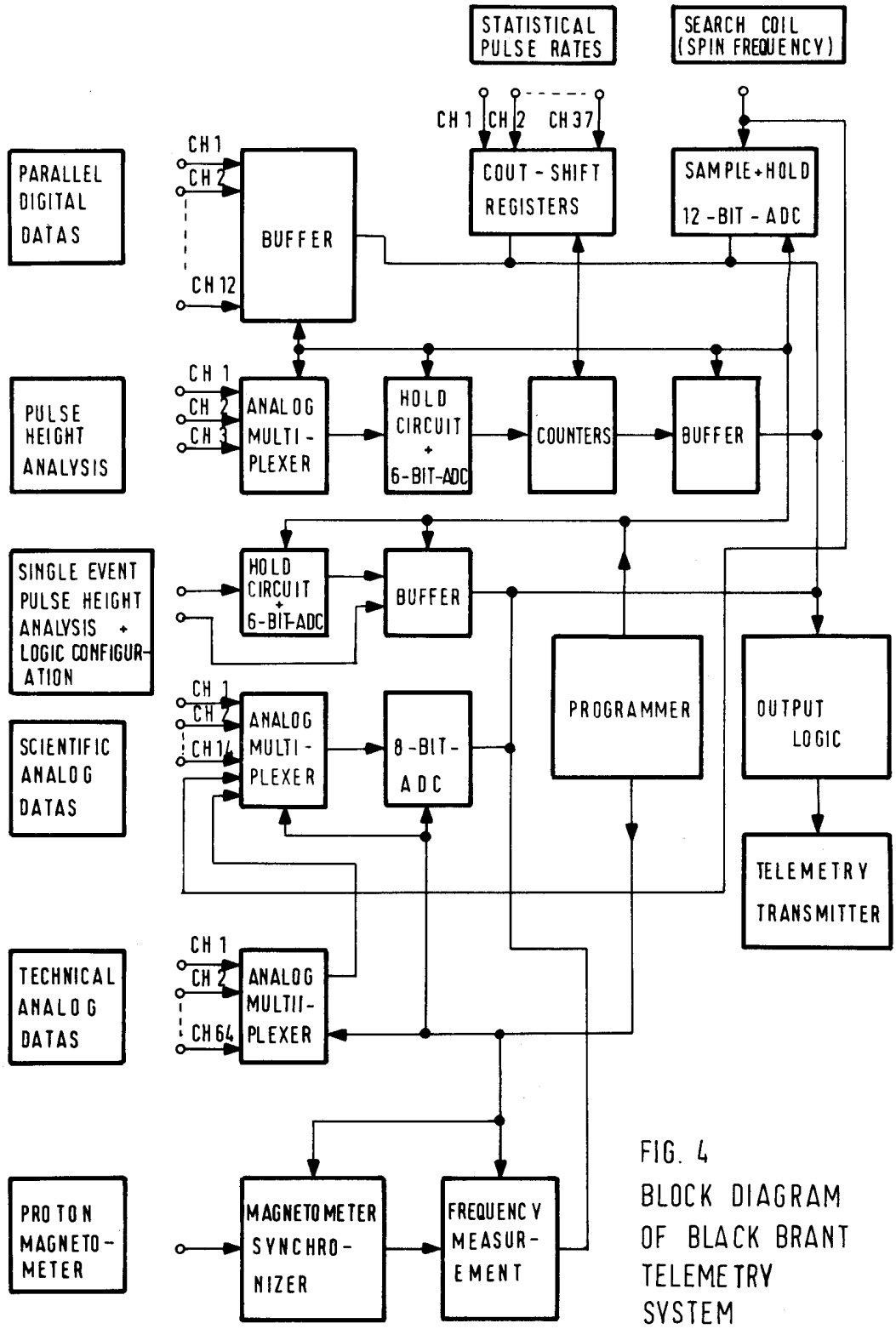


FIG. 4
BLOCK DIAGRAM OF BLACK BRANT TELEMETRY SYSTEM

Fig. 5 Examples of Thick Film Components (size 29x2ox3 mm or 2ox1ox3 mm, respectively)