

RADIATION HARD STANDARD ASICS FOR ON-BOARD APPLICATIONS

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ABSTRACT

Standard ASICs for on-board applications are being developed within an ESA/ESTEC contract with *Dornier Satellitensysteme GmbH* as the prime contractor. The main goal of this contract is to provide key components to the space user community, which are used in various applications. The goal is to reduce development effort for nearly identical applications needed by different companies, leading to a cost saving in the overall context. The frame contract covers the development of a Local Time Management System (LTMS), a Reed-Solomon and Convolutional Encoder (RESCUE) and a Packet Telecommand Decoder (PTCD). The RESCUE and the PTCD chip are replacements for the discontinued MA1916 and MA28140 (PTD) from GPS (UK). All these standard ASICs are being manufactured by MITEL Semiconductor (S) based on their CMOS/SOS5-process.

1. Introduction

This paper describes the ESA/ESTEC approach to develop Standard ASICs for on-board applications. The ASIC developments performed within the “*Radiation Hard Data Handling Technology*” frame contract are summarized in terms of functionality of the devices, process characteristics, current status and availability of parts to potential users.

2. Standard ASICs for Space Applications (ASSPs)

A *Standard ASIC* (sometimes referred to as an *Application Specific Standard Product, ASSP*) is defined as a device developed in the same way as an ASIC, but with the intention to be widely used by other

companies, in a way similar to a standard component. It has the following characteristics:

- The device is specified to meet multiple applications
- The device is designed normally by another company than the foundry
- The device is manufactured in ASIC technology
- After the development, the device shall be available to European companies under equal conditions from the foundry, including distribution of data sheets and basic support to customers.

The objective of the “*Radiation Hard Data Handling Technology*” frame contract is to develop such Standard ASICs for typical, or better, recurring on-board functions. The intention of ESA/ESTEC is, of course, also to save money in the overall context, since duplications of nearly identical ASIC developments in several companies shall be minimized as far as possible.

3. The “Radiation Hard Data Handling Technology (RDT)” - Frame Contract

To design and manufacture ASSPs for on-board applications, ESTEC has issued an Invitation to Tender (ITT) end of 1994. The activity should be handled as a frame contract, with so-called “call-off orders” for the different applications.

The objectives of this contract are the following:

- Design and manufacture devices suitable for on-board applications
- Create a comprehensive data sheet and a VHDL model for board-level simulation for each device
- Ensure that the devices are available from and supported by the foundry as Standard ASICs
- Qualify the manufactured devices according to ESA/SCC requirements

CO #	Activity	Involved Partners	Status
1	Local Time Management System (LTMS)	IMEC (B) - Design MITEL (S) - Foundry DSS (D) - Prime	LTMS version B is in manufacturing
2	Study on a Generic CCD-Controller (GCC)	DSS (D)	Study has been concluded with a preliminary specification
3	Reed-Solomon and Convolutional Encoder Cores	Smartech (Fin) - Design DSS (D) - Prime, Separate Verification	Activity is finalized, cores are reused in CO #5
4	Memory Core Development	MITEL (F) - Design and layout DSS (D) - Prime	Activity is finalized, memory core is reused in CO #5
5	Reed-Solomon and Convolutional Encoder (RESCUE)	Smartech (Fi) - Design MITEL (S) - Foundry DSS (D) - Prime, Separate Verification	Activity is on-going, manufacturing of the device is in progress
6	Packet Telecommand Decoder (PTCD)	MMS (F) - Design transfer MITEL (S) - Foundry DSS (D) - Prime	Activity is on-going, manufacturing of the device is in progress

Table 1: Radiation Hard Data Handling Technology - Frame Contract

The RDT frame contract has been placed with Dornier Satellitensysteme GmbH - DSS (D) as the prime contractor in April, 1995, with the Local Time Management System (LTMS) as the first call-off order.

Table 1 lists the call-off orders already performed or currently being in progress and summarizes their actual status as of mid of May, 1998.

4. The CMOS/SOS5 Process of MITEL Semiconductor (S)

All three ASICs currently in the manufacturing phase are targeted for the SOS5 process from MITEL Semiconductor (the former ABB HAFO) from Sweden. This process is the continuation of the well characterized SOS4 process, developed for digital applications at the end of the 80's, which is now also being used for analog and high voltage applications. The SOS4 process and design are covered for digital ASICs by an ESTEC/ESA Capability Domain Approval. This Capability Domain covers all aspects of the ASIC development and manufacturing up to the HiRel device delivery (ESA/SCC 9000 level B). The SOS5 process is in the final stage of receiving the capability domain approval (expected in 1998).

The experience gained with SOS4 has been transferred into the state-of-the-art SOS5 process. Tool and library improvements allow integration of more than 35,000 gates (random logic) into an ASIC.

The key features of the SOS5 process are given in table 2 (with comparative SOS4 values):

	SOS 4	SOS 5
Total Dose	> 100 kRad (Si)	> 100 kRad (Si)
Single Event Upset	Virtually immune	Virtually immune
Latch up	Immune	Immune
Dimension	2 μm	1.25 μm
Propagation Delay	1.0 ns	0.5 ns
Density	700 tr/mm ²	1750 tr/mm ²
Power Supply	3-7 V _{DC}	3-7 V _{DC}

Table 2: SOS5 process features

For SOS5 front-end design SYNOPSIS, SYNERGY, CADENCE and MENTOR Graphics tools are supported. Used as the golden platform for SOS5 (*Verilog-XL* is the sign-off simulator), the CADENCE design-kit includes also the back-end utilities for layout down to the GDSII file.

5. Local Time Management System (LTMS), MS_13196

The LTMS (Local Time Management System) is the key element of a decentralised time distribution scheme [1]. Local copies of the centralised Elapsed Time (ET) reference of a spacecraft are maintained by LTMS devices located close to the users. The central ET reference is assumed to be managed by a Central Time Management System (CTMS) being an integrated part of the on-board data handling system. The coherence between the local ET references and the central ET reference is maintained by means of time synchroni-

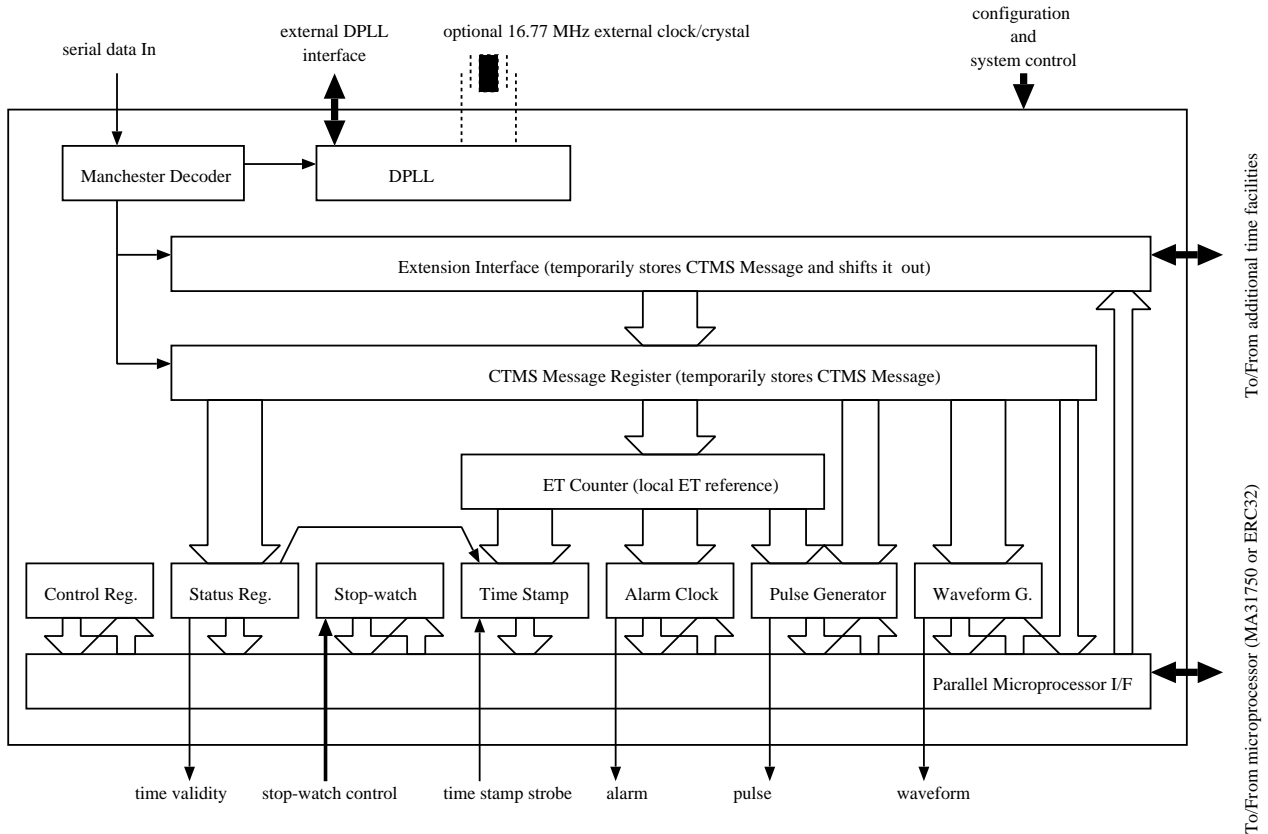


Figure 1: LTMS blockdiagram

sation messages [2] distributed by the CTMS. The LTMS performs regular synchronisations with respect to the central ET reference using such messages and provides its users with several time facilities related to the local ET reference (as depicted in figure 1): a Time-Stamp, an Alarm Clock, a Pulse Generator, a Waveform Generator and a Stop-Watch.

At present, the LTMS is being manufactured. Prototypes are planned to be available in May, 1998. MITEL Semiconductor intends to deliver flight parts from October, 1998 onwards.

Most LTMS applications are expected to involve the ESA OBDH bus. Figure 2 shows a typical LTMS configuration where the LTMS is connected to the OBDH bus through a Data Bus Unit (DBU) and a Remote Bus Interface (RBI). The CTMS is assumed to be integrated into the interrogation generator of the OBDH Central Data Management Unit (CDMU). To broadcast time information to all the LTMS components in the spacecraft, the CDMU modulates one of the Broadcast Pulse (BCP) Bits transmitted in each 32 bit bus interrogation. This virtual serial line is coherent with the central elapsed time clock and has an effective bandwidth of one sixty-fourth of the bus bit rate, which is more than enough to carry the time

messages, the synchronisation pulses and the phase references.

In the configuration shown, the LTMS operates in serial mode. To get the very highest solution, the clock driving its ET counter is generated by a 16,77 MHz crystal directly connected to the built-in crystal oscillator cell. The internal DPLL adjusts this clock to the phase reference carried on the BCP output of the RBI chip. The synchronisation process between the LTMS and the CTMS is completely transparent to the application. Even after a complete reset of the application, no support from the processor is required since the LTMS will automatically synchronise its ET counter to the central time reference.

Previous implementations of time distribution have required extensive support from the application processor. One particular protocol required that the CDMU ordered each user to enable the time counter to be reset on reception of a broadcast pulse. This was performed by means of an OBDH bus interrogation. Next, the value of the central time reference at the reset instance was broadcast and had to be added to the local time counters by the application processor. As a last step, the users were ordered by an interrogation to disable further resets of the counter in question. It is clear that this protocol caused discontinuities in local

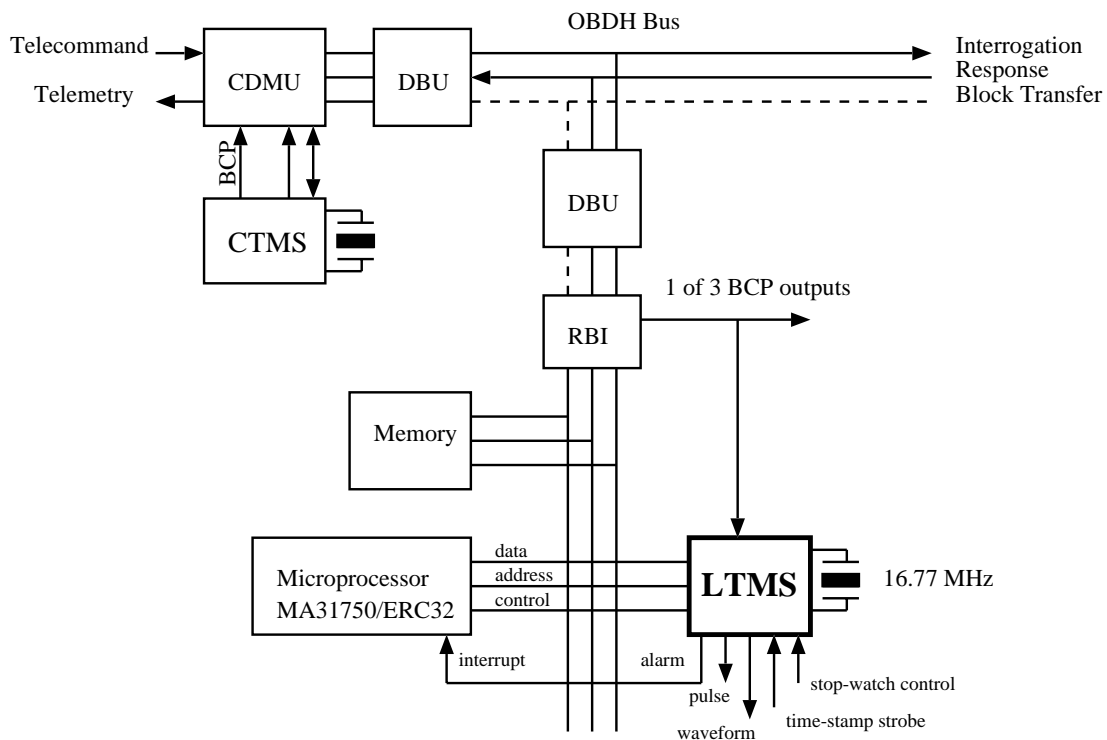


Figure 2: The LTMS in a typical OBDH system configuration

time counters that could result in incorrect time information being provided to users. It also required a high level of involvement from the application processors to achieve time coherence throughout the spacecraft. The new standard protocol implemented by the LTMS relieves the application processor from such duties. It also avoids discontinuities in the local time counters and provides high resolution.

6. Reed-Solomon and Convolutional Encoder (RESCUE), MS_13544

The Reed-Solomon and Convolutional Encoder (RESCUE) shall replace the discontinued MA1916 device from GEC Plessey Semiconductor-GPS (UK). RESCUE is a device for coding telemetry channel data according to the ESA Telemetry Channel Coding standard [3] supporting the ESA Packet Telemetry Standard [4]. The RESCUE device can be viewed as four separate but interconnected encoders as presented in the blockdiagram in figure 3.

The Reed-Solomon encoder generates code blocks by receiving information symbols which are transmitted unmodified while calculating the corresponding check symbols which are transmitted in their turn after the information symbols. When unmodified data is received and transmitted such as synchronisation

markers, the check symbol calculation is disabled. The calculation is independent of any previous code block and is performed correctly on the reception of the first information symbol after a reset.

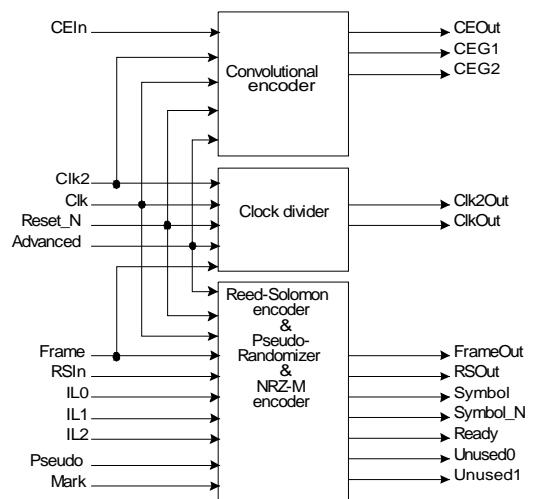


Figure 3: RESCUE blockdiagram

The Pseudo-Randomiser generates a standardized pseudo-random bit sequence, which is optionally mixed with the Reed-Solomon encoder output. This function

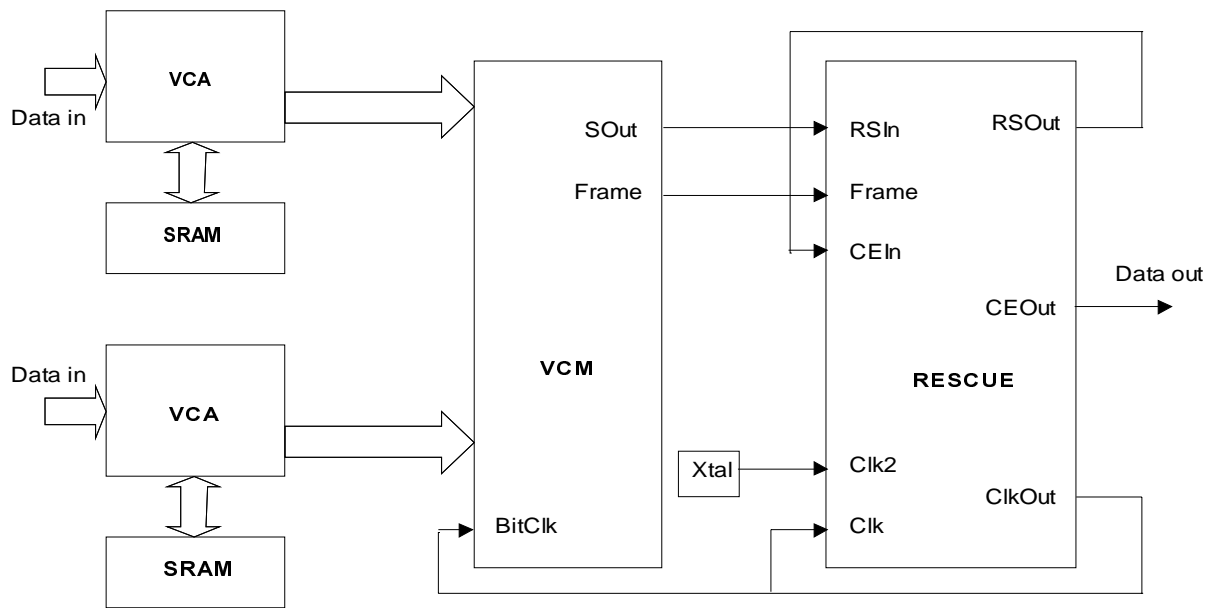


Figure 4: Telemetry encoder implemented with VCA, VCM and RESCUE devices

can be used to obtain the required bit transition density on a channel to enable a receiver on ground to maintain bit synchronisation. The output stream can optionally be NRZ-M encoded.

The Convolutional encoder receives data bitwise and synchronously with an input bit clock. For each input bit two symbol bits are generated and are output both serially and in parallel.

At present, the RESCUE device is in the manufacturing phase. Prototypes are planned to be available in August, 1998. MITEL Semiconductor intends to deliver flight parts from January, 1999 onwards.

The RESCUE device is foreseen to be used in **telemetry encoders** on ESA and commercial spacecraft, replacing the discontinued MA1916 device. The principal functions of a telemetry encoder is to receive data from the on board data handling system to be formatted and output. The data can be received on virtual channels, where each virtual channel can be seen as an independent communication link. Since there is only one physical output from the telemetry encoder, the data from the virtual channels are time multiplexed on a frame basis. The telemetry encoder generates the Attached Synchronisation Marker (ASM), the header and the optional trailer of the Transfer Frame and the optional Reed-Solomon check symbols. Optionally, the resulting data stream is convolutionally encoded.

The Virtual Channel Assembler (VCA) and the Virtual Channel Multiplexer (VCM) are radiation-hard devices that together with the RESCUE device can be used for implementing a telemetry encoder. A block diagram of a typical telemetry encoder is shown in figure 4, comprising one VCA and one SRAM per virtual channel, a VCM and a RESCUE device. In this example the RESCUE device is operating in Advanced mode and is directly interfaced to the VCM, generating Reed-Solomon symbols (with optional pseudo-randomising and NRZ-M encoding) and convolutionally encoding the data.

7. Packet Telecommand Decoder (PTCD), MS_13545

The PTCD shall replace the discontinued MA28140 device from GPS (UK). The device shall be drop-in compatible with the MA28140. Therefore a design transfer with only minor modifications of the original data base to the SOS5 process is performed. As depicted in the blockdiagram in figure 5, the PTCD features 7 major blocks described below. The PTCD deals with the Coding Layer, the Transfer Layer, the Segmentation Layer and a part of the Packetisation Layer of the CCSDS protocol.

The **Coding Layer Block** multiplexes the 6 physical TC channel inputs and fulfils the coding layer function described in section 5 of [5]. The main tasks performed by the PTCD at this level are start sequence detection

and selection of the first active TC input, codeblock error detection and correction, valid codeblock transfer to the above layer and generation of part of the Frame Analysis Report (FAR) and the Command Link Control Word (CLCW) status.

The **Transfer Layer Block** is concerned with the processing of the frames received from the coding layer and fulfils the transfer layer function described in section 6 of [5]. At this level, the PTC D performs clean frame validation, legal frame validation, frame analysis report mechanism and reporting word (16 bit CLCW and part of 32 bit FAR) generation.

The **Authentication Unit** (which is optional and can be disabled permanently or during flight) is concerned with the segment data protection. It enables the spacecraft to authenticate the received data. The authentication concept is the „plain text with appended signature“ approach, described in Section 8 of [6]. In the PTC D architecture this function is implemented on chip. However, a specific interface allows authentication to be performed externally. If another coding algorithm is to be used, the on-chip block can be disabled and an external authentication system can be used. The block generates a reporting word (Authentication Status = 80 bits) and part of the 32 bit FAR.

The **Segmentation Layer Block** implements only some of the segmentation layer functions described in section

7 of [5]. Its purpose is to manage the back-end buffer shared with the FARM-1 block of the transfer layer and to implement the MAP interface in order to demultiplex (with external hardware) the segments dedicated to the different spacecraft applications.

The **Command Pulse Distribution Unit (CPDU)** is integrated into the PTC D ensuring higher reliability for this critical function (direct telecommand for spacecraft reconfiguration) than if implemented in an external chip. The critical commands executed by the CPDU are received in specific packets. The CPDU responds to the MAP identifier 0, and to a mission dependent application process identifier (stored in ROM). No segmentation is accepted, the commands must be contained in an unsegmented package. The unit generates a reporting word (CPDU Status = 16 bits).

The **Bus Controller** is the interface between external memories and on chip modules. Its different functions include address decoding as well as internal and external bus access arbitration.

The **Telemetry Module** block is the interface with the telemetry subsystem. It manages the data report storage by the means of two registers.

At present, the PTC D is in the manufacturing phase. Prototypes are planned to be available in September, 1998. MITEL Semiconductor (S) intends to deliver flight parts from January, 1999 onwards

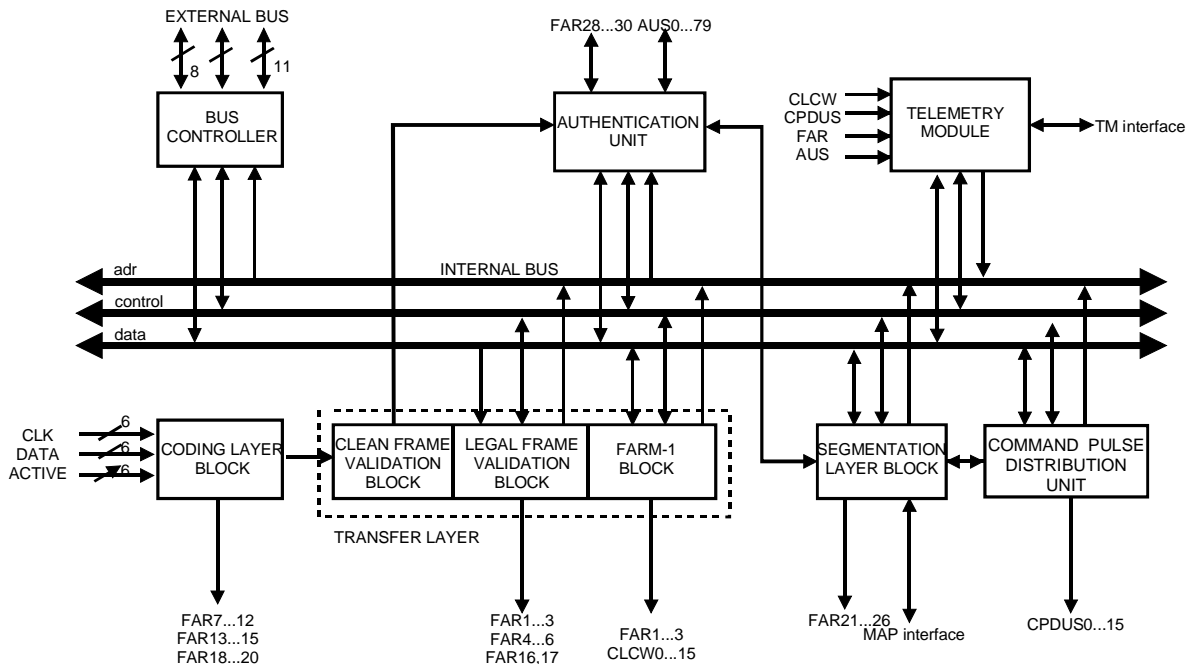


Figure 5: PTC D blockdiagram

An **ESA/CCSDS Telecommand Decoder subsystem** including the PTCD and fulfilling the receiving-end functions established in the Packet Telecommand Standard [5] is shown in Figure 6.

The PTCD requires the following additional hardware to fulfil the requirements of the Telecommand Decoder Specification [6]:

- Transponder I/F including demodulators for PSK TC inputs.
- Telemetry I/F: the telemetry reporting signals can be directly connected to a Virtual Channel Multiplexer (ref. 3).
- Command Pulse Distribution Unit I/F: This function performs decoding of commands present on the local bus and power amplification. The PTCD ASIC associated with the CPDU I/F can manage 256 pulse outputs.
- MAP demultiplexer I/F: this interface is composed of a demultiplexer to provide the TC segment data to various Data Management System interfaces. The demultiplexer is controlled by the MAP data present on the Local Bus. The PTCD ASIC can manage 62

different serial data interfaces (63 if AU is disabled).

- Memories. There are 2 different memories:
 - RAM (2Kx8) used to store the received TC data and protocol variables (e.g. programme authentication) and eventually to store the TC segment available for further processing by the Data Management System. If this memory is used to store the recovery LAC counter (Authentication function), it must be a non-volatile memory.
 - ROM (1Kx8) divided in two parts:
 1. Configuration part for Mission Specific Data.
 2. Authentication part, used to provide the fixed Authentication key.
- External Authentication Unit (optional). Although an AU is implemented in the PTCD, it is also possible to use an external AU if the mission requires a different authentication algorithm. This external unit accesses the RAM in order to authenticate a TC segment.

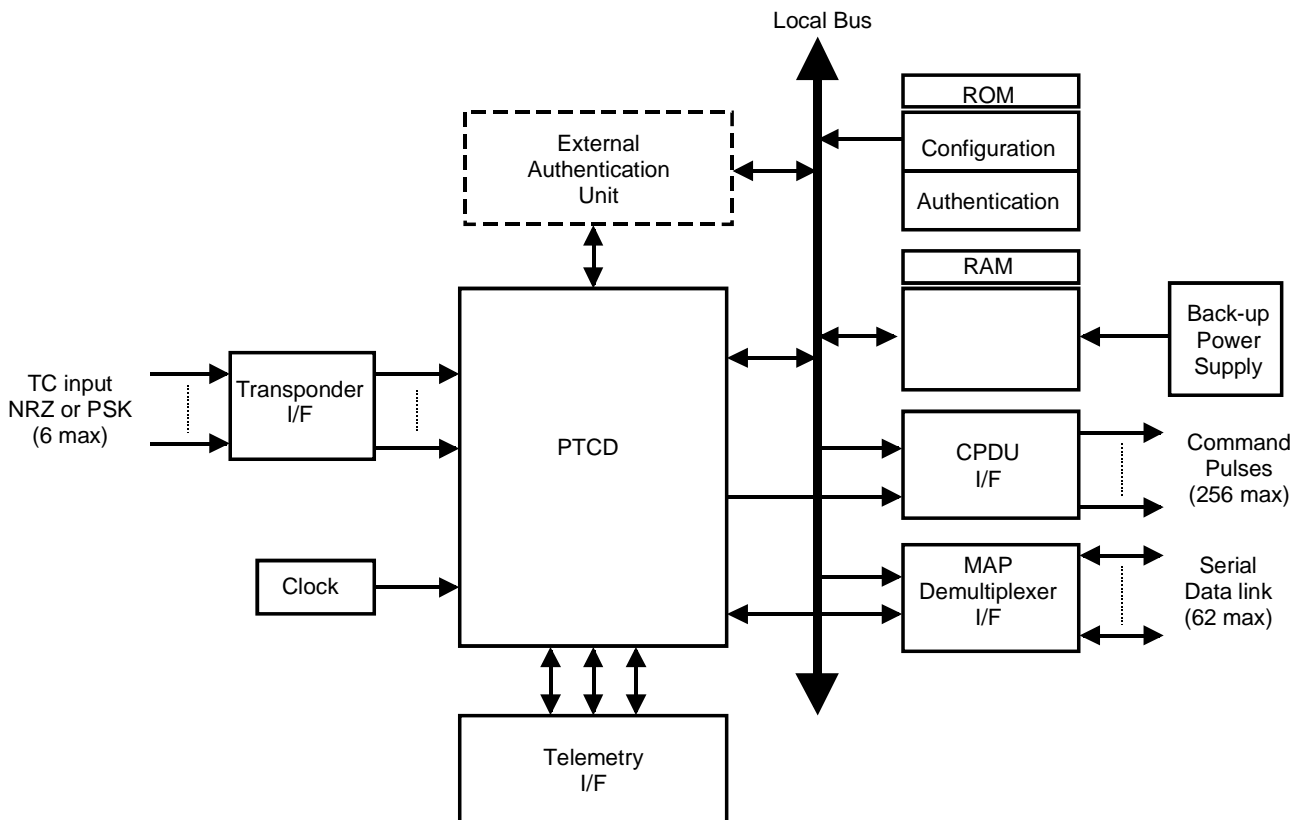


Figure 6: Telecommand decoder based on the PTCD device

8. Conclusions

Within the RDT frame contract three key components for on-board applications are being developed in radiation hard SOS-technology from MITEL Semiconductor (S). All devices shall be available in 1998 and early 1999 for the space community.

Questions regarding price and availability of the devices should be directed to Mr. Göran Wennergren at MITEL Semiconductor (+46-8-580 24635).

9. Further Informations

Several documents and information can be downloaded in electronic format as listed hereafter:

- RESCUE - Reed-Solomon and Convolutional Encoder, Preliminary Data Sheet
www.smartech.fi/MA13544.pdf
- A Local Time Management System ASSP
ftp.estec.esa.nl/pub/vhdl/doc/LTMS.pdf
- Local Time Management System Validation Board
ftp.estec.esa.nl/pub/vhdl/doc/CTMS.pdf
- ASIC Design and Manufacturing Requirements
ftp.estec.esa.nl/pub/vhdl/doc/DesignReq.pdf
- VHDL Modelling Guidelines
ftp.estec.esa.nl/pub/vhdl/doc/ModelGuide.pdf
- Components for Building Telecommand and Telemetry On-board Systems
ftp.estec.esa.nl/pub/vhdl/doc/TmTc.ps

10. Acknowledgements

The authors only represent a minority of the complete RDT design team and therefore wish to acknowledge the most substantial contribution of the other team members. In particular these are, for

IMEC: B. De Mey, G. Vanwijnsberghe, S. Dupont, S. Redant

SMARTECH: J. Tomberg, A. Rääkkönen, H. Rantalainen

MMS-F: M. Souyri, N. Perrot

MITEL: B. Larsson, P. Selander, J. Richaud, M. Soerder, P. Le Bohec, G. Wennergren

ESTEC: P. Sinander, D. Maeusli, P. Armbruster

DSS: D. Viehmann, O. Birk and Dr. E. Krahn.

11. Acronyms and Abbreviations

ASIC	Application Specific Integrated Circuit
ASSP	Application Specific Standard Product
BCP	BroadCast Pulse
CCSDS	Consultative Committee for Space Data Systems
CDMU	Central Data Management Unit
CMOS	Complementary Metal Oxide Semiconductor
CLCW	Command Link Control Word
CTMS	Central Time Management System
CUS	CCSDS Unsegmented Code
DBU	Data Bus Unit
DPLL	Digital Phase Locked Loop
ERC32	Embedded Real-Time Computer
ET	Elapsed Time
FAR	Frame Analysis Report
IEEE	Institute of Electrical and Electronics Engineers
LTMS	Local Time Management System
OBDAH	On-Board Data Handling
PTCD	Packet Telecommand Decoder
RBI	Remote Bus Interface
RESCUE	Reed-Solomon and Convolutional Encoder
SEU	Single Event Upset
SOS	Silicon on Sapphire
VCA	Virtual Channel Assembler
VCM	Virtual Channel Multiplexer
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit

12. References

- [1] "A Local Time Management System ASSP", S. Redant (IMEC) and S. Habinc (ESTEC); Proceedings of the ESA Microelectronics Workshop, December 1996 (Session 2C)
- [2] "4-255 Data Bus Protocol Extensions", PSS-04-256
- [3] Telemetry Channel Coding Standard, ESA PSS-04-104, Issue 1, September 1989
- [4] Packet Telemetry Standard, ESA PSS-04-106, Issue 1, January 1988
- [5] Packet Telecommand Standard, ESA PSS-04-107, Issue 2, April 1992
- [6] Telecommand Decoder Specification, ESA PSS-04-151, Issue 1, September 1993