A REAL-TIME LABORATORY COMPUTER-BASED SPEECH PROCESSOR FOR COCHLEAR IMPLANT RESEARCH

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ABSTRACT - The hardware and software development for a real-time laboratory computer-based speech processor for cochlear implant research is described. It is envisaged that this processor will also be suitable for other areas of research such as electro-neurophysiology.

INTRODUCTION

A real-time laboratory computer-based speech processor is being developed to permit speech processing and perception studies on prospective speech processing schemes for cochlear implant prostheses. The speech processor will be interfaced with cochlear implant receiver-stimulators for studies on cochlear implant patients. In addition, the processor will also be interfaced with acoustic transducers so that parallel studies can be performed on normally hearing subjects by using acoustic stimuli whose psychophsical characteristics are similar to those of the electric stimuli used in implant patients.

REAL-TIME LABORATORY COMPUTER-BASED SPEECH PROCESSOR

There are three major components in the laboratory computer-based speech processor: a VAX-11/730 computer, a PDP-11/23 computer, and a real-time programmable digital signal processor (RPDSP). The input acoustic speech signal is picked up by a microphone, and digitized by an analog-to-digital conversion system in the RPDSP. The RPDSP handles real-time simulation of the following functions: (i) acoustic speech parameter estimation; (ii) acoustic-to-electric parameter conversion; (iii) synthesis of acoustic stimuli for normally hearing subjects, and (iv) generation of control codes for electric stimuli to be presented to cochlear implant patients. The DEC PDP-11/23 minicomputer is linked with the RPDSP. Its function is to accept RPDSP programs from the VAX-11/730, to download these programs to the RPDSP and to control the execution of these programs. The PDP-11 will also store patient-specific psychophysical data to be used in the acoustic-to-electric parameter conversion in the speech processor, and will download these data to data memories in the RPDSP for the generation of control codes for electric stimuli. It will also gather time series of the digitized speech signal and parameter values at different stages of speech processing in the RPDSP for real-time display and later analysis. Alternatively, these time-series data can be transferred to the VAX-11/730 for display and further non-real-time analysis.

The VAX-11/730 is used to provide software development facilities for the RPDSP, and to perform non-real-time simulation of the signal processing blocks to be implemented in the RPDSP.

HARDWARE DESCRIPTIONS OF THE RPDSP

A block diagram of the RPDSP is shown in Fig. 1. The RPDSP contains seven CPU modules, a central Global Memory module, a Global Memory bus for communications amongst the 7 CPU's and the PDP-11/23, an interrupt line from the PDP-11/23 to the 7 CPU's, a program synchronization clock for the 7 CPU's, and a direct 16 bit I/O interface between one of the CPU's and the PDP-11/23 for high speed data transfer (e.g. to transfer pre-recorded sampled speech data from the PDP-11/23 to the CPU in place of real-time A/D conversion in the CPU).

Each CPU module contains:

(i) one Texas Instruments TMS 32010 Digital signal processing chip;
(ii) read-only-memory for storage and execution of control programs which communicate with the PDP-11/23 via the Global Memory;
(iii) random-access-memory for storage and execution of signal processing programs (downloaded from the PDP-11/23) which perform the acoustic parameter extraction, acoustic-to-electric parameter conversion, and electric (or acoustic) stimulus generation functions;
(iv) READ/WRITE/ADDRESS latches, and bus/control circuits to gain access to the Global Memory module for communication with other CPU's and the PDP-11/23;
(v) optional analog-to-digital converter for the acquisition of acoustic input signal;
(vi) optional digital-to-analog converter for the generation of acoustic stimuli,
(vii) optional digital output to radio frequency transmitter for cochlear implant receiver-stimulators which deliver electric current pulse stimuli to an implanted electrode-array;
(viii) miscellaneous address and control circuitry.

The Global Memory module contains a block of random access memory accessible by all CPU modules and the PDP-11/23 thus enabling the transfer of data and timing information amongst these units. Note that a special interface has been developed so that the PDP-11/23 appears the same as a CPU module to the global memory and operates in the same way.

SOFTWARE DESCRIPTIONS OF THE COMPUTER-BASED SPEECH PROCESSOR

The control programs and the signal processing programs residing respectively in the ROM and RAM of the CPU's in the RPDSP are written in TMS-320 assembly language, and developed on the VAS-11/730. The control programs handle the communication amongst the CPU's and the PDP-11/23, while the signal processing programs perform the various signal processing functions. The VAX-11/730 supports cross assembler/editor/linker/simulator software for the TMS32010.

The assembled and linked object codes of the control and signal processing programs are generated on the VAX, and converted to the correct format suitable for the PROM programmer (control programs), and for downloading to the CPU's (signal processing programs).

The object codes of the signal processing programs are first transfered from the VAX to the PDP-11 using the file transfer program "Kermit" from the DECUS library. These codes are then downloaded to the CPU's by running a special monitor program (developed in house) on the PDP-11 in conjunction with the control programs on the CPU's. In addition to program downloading, the monitor program (PDP-11) communicates with the CPU control programs to perform the following functions:
(i) to supervise and monitor the operation of the signal processing programs in the CPU's; and (ii) to send a time series of the digitized input signal (to the signal processing programs) and parameter values at different stages of signal processing to the PDP-11. These time series can subsequently be sent to the VAX using "Kermit" for further analysis. Graphics routines have also been developed on the VAX and the PDP-11 to display these time series. These routines are useful for the examination of the time series during both real-time and non-real-time verification of the performance of the signal processing programs to be described in the next paragraph.

To support the development of the signal processing programs (in TMS-320 assembly language), a number of software facilities have been implemented on the VAX-11/730. A library is created containing macros which perform the various signal processing functions. For the implementation of a particular speech processing scheme, a file which contains TMS-320 source code (including elements of the macro library) defining the signal processing system is created. The source code in this file is assembled and linked and the operation of the signal processing system can be verified using the non-real-time simulator supplied by Texas Instruments. The linked (and verified) object code is then downloaded to the RPDSP for further verification and debugging under real-time operation conditions.

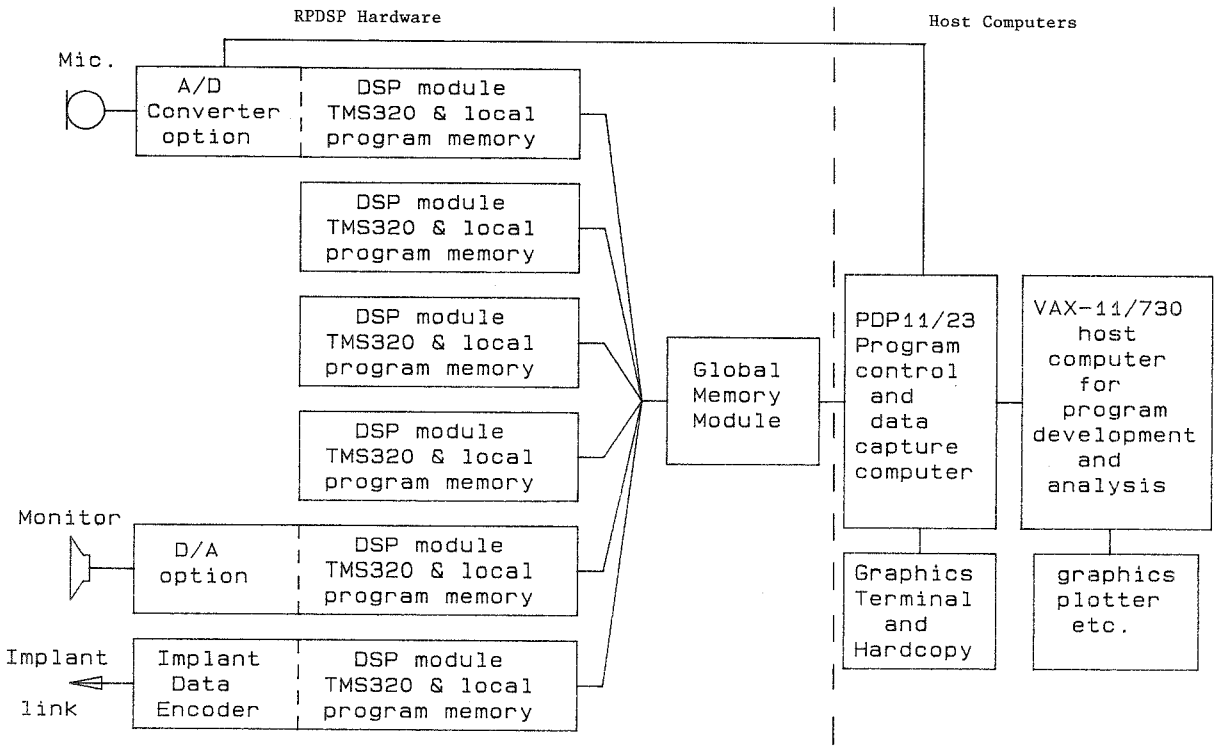

Fig 1. Real-time Programmable Digital Signal Processor.