Computerized Tomography Using Ultrasound: System Design*

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Editor's Note: This very initial publication of methodology relating to the use of ultrasound in performing computerized scans is published so that our readers may have an insight into an existing new diagnostic tool. Ultrasound rather than x-ray has an obvious use in pregnancy and many other conditions where radiation might not be advisable. This work is in its early stages and clinical usage is not yet available. Clinical trials may be ready within a year or two.

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INTRODUCTION

Virtually all the computerized tomography scanners in clinical use at the present time utilize x-rays. The system described in this paper uses ultrasound instead, thus eliminating x-ray exposure. The images obtained depend on tissue properties such as the absorption of ultrasound, rather than x-ray density.

Living tissues can be characterized by their interaction with ultrasound. Our research involves measuring the frequency-dependent amplitude and time-of-flight of ultrasound after it passes through biological materials. These measurements are processed to produce tomographic images of the material being studied. The tomographic images yield resolutions of 0.5 cm in the low MHz ultrasonic frequency range.

This paper describes the data-acquisition circuitry of a computerized tomography system, as part of a joint effort with Mayo Clinic (J.F. Greenleaf) and Purdue University (A.C. Kak). A block diagram of the system is given in Fig. 1.

SYSTEM DESCRIPTION

All the image-reconstruction tasks and experiment controls are handled by an Interdata 7/32 computer, and all communications of the system to the Interdata 7/32 are performed by an analog-to-digital (A/D) input channel and two digital input/output ports (DIO). A device controller is responsible for interfacing the different data-acquisition electronics to the Interdata 7/32.

The ultrasound signal is either a single broadband pulse or a discrete-frequency tone burst. The signal source is an HP 8660B sine-wave synthesizer (output frequency range 0.01 - 110 MHz) whose frequency and amplitude are programmable and controlled by the Interdata 7/32. In order to free the zero-crossing detection circuit, which is the front end of the programmable window generator, from the constraints of the low signal amplitude, the signal amplitude of the HP 8660B is set constantly at maximum.

The synthesizer output drives a high-speed FET input buffer amplifier, which in turn drives a programmable attenuator and a programmable window generator. The programmable attenuator varies the signal output of the buffer amplifier in 64 steps and has a dynamic range of 36 db. The programmable window generator utilizes high-speed Schottky TTL logic chips which have minimal gate delays to produce a window coherent with the signal zero-crossings.

This window generator can produce a window with a width to 0.5, 1, 2, 4, 8, 16, 32, 64 or 128 cycles of the signal. The window signal and the programmable attenuator output are mixed by a double balanced mixer (DBM), producing a pulse of appropriate width and amplitude. The signal is then amplified by a power amplifier, which in turn excites the transmit transducer to transmit an ultrasound signal through the tissue under test.

Measurement of the time-of-flight of the ultrasound signal requires averaging many signals with an HP 5328A Universal Counter, the resolution obtained depending on the number of intervals averaged. A two-nanosecond resolution is desirable in some measurements, and requires averaging 100 intervals. The HP 5328A Universal Counter is started by triggering its channel A input with a rising edge generated by a clipper. The clipper is actually a signal detection circuit which generates a rising edge to trigger channel A of the counter when any signal occurs at the DBM output.

After the signal passes through the tissue under test, it is detected by an ultrasonic transducer and amplified by an HP 461A amplifier. The amplified signal causes the clipper to generate another rising edge, triggering channel B of the HP 5328A Universal Counter to stop after the appropriate number of intervals, thus yielding time-of-flight data.

When discrete-frequency tone bursts are transmitted, the amplifier drives a programmable filter with selected cutoffs to reduce noise. The filtered signal is then further amplified by a four-stage programmable gain amplifier to condition the signal to an appropriate amplitude range for a pulse-height detector. The pulse-height detector produces a DC level output proportional to the peak, rectified signal amplitude. This DC level is then digitized through an A/D input channel by an analog-to-digital converter in the Interdata 7/32.

The programmable filter and the pulse-height detector are bypassed for a broadband pulse. The signal output of the HP 461A is amplified by the programmable amplifier and goes through a buffer amplifier to a TRW 8-BIT video analog-to-digital converter (TEC 1007J), which has a sampling rate of 30 MHz.

A high-speed parallel memory buffer must be used to buffer all the data points. A parallel memory system is used to obtain a high data-transfer rate. By sequential clocking of several blocks of slower memories, a higher band-width is achieved to match the 30-MHz sampling rate. The memory buffer empties its contents to the Interdata 7/32 through DIO 2. Further signal analysis by the Interdata computer produces tomographic images. Appropriate signal processing such as Fourier analysis can then be performed.

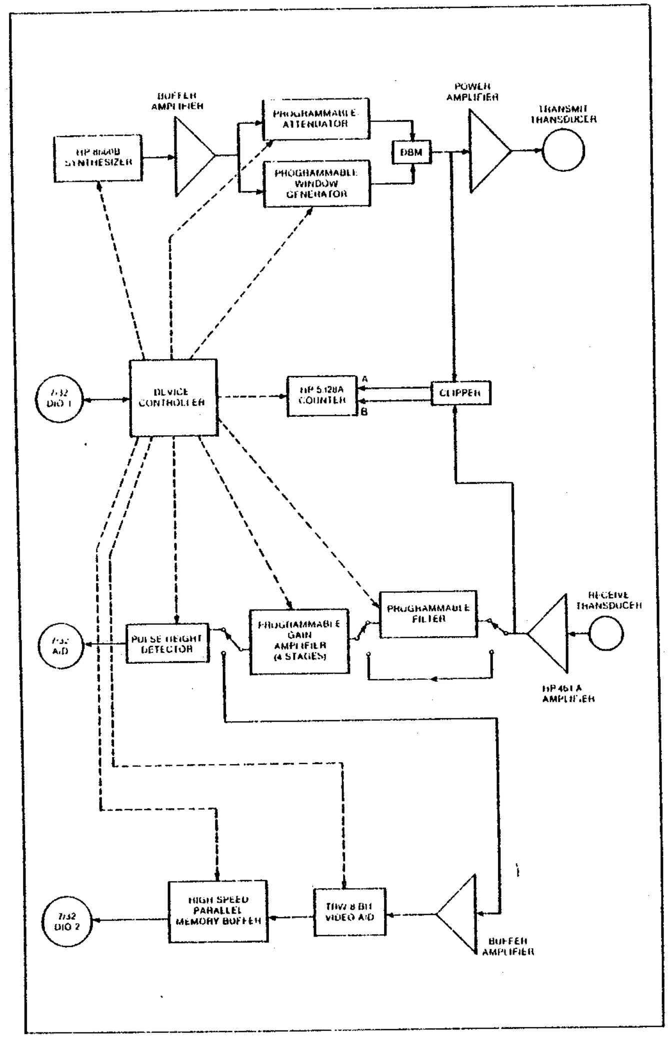

Fig. 1 — System block diagram.

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