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Abstract
An ultrasonic acquisition and processing system is being developed which incorporates a real time CCD averager. The averager sums the received ultrasonic signal with the weighted past average to produce the latest average. The averager performance is a function of scan resolution, signal repetition rate, scan velocity, CCD clock rate, weighting value and number of averages desired. The present averager should provide a theoretical improvement in signal to noise of 6 dB. Aside from improving the signal strength at the present scan position the averager is designed such that the signal level from the previous scan location has decayed by at least 10 dB. The paper will discuss averager results, and the various design considerations and simulation testing required to achieve and verify averager performance.

Keywords
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Disciplines
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REAL TIME CCD AVERAGER FOR ULTRASONIC APPLICATIONS

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ABSTRACT

An ultrasonic acquisition and processing system is being developed which incorporates a real time CCD averager. The averager sums the received ultrasonic signal with the weighted past average to produce the latest average. The averager performance is a function of scan resolution, signal repetition rate, scan velocity, CCD clock rate, weighting value and number of averages desired. The present averager should provide a theoretical improvement in signal to noise of 6 dB. Aside from improving the signal strength at the present scan position the averager is designed such that the signal level from the previous scan location has decayed by at least 10 dB. The paper will discuss averager results, and the various design considerations and simulation testing required to achieve and verify averager performance.

GENERAL DESCRIPTION - THE AVERAGER IS BEING CONSTRUCTED FOR USE IN ULTRASONIC PROCESSING SYSTEMS WHERE SIGNAL TO NOISE ENHANCEMENT IS REQUIRED. THE AVERAGER IS INSERTED BETWEEN THE TRANSDUCER AND DETECTOR TO SUPPLY CONTINUOUSLY WEIGHTED rf SIGNAL AVERAGES TO THE DETECTOR. THE AVERAGER REQUIRES A TRIGGER PULSE WHICH IS IN SYNCHRONISM WITH THE PULSED SIGNAL.

CHARACTERISTICS

- INPUT PROTECTION - CLIP MAIN PULSE TO ACCEPTABLE LEVEL.
- FILTERING - ENHANCE FREQUENCY REGION OF 3.5 MHZ SIGNAL AND REDUCE DIGITIZING FREQUENCY, 12.5 MHZ.
- CCD CLOCK CONTROL - ALLOW SYNCHRONOUS AND CONTROLLED TIMING OF CCD CLOCKING WITH PULSER.

Fig. 1. Real time CCD averager for ultrasonic application

Fig. 2. Design considerations

Decay of CCD Signal/Noise Increase
Time Delay and Phase Shift of Averager Loop
Filtering of CCD Clock and Signal
Received Amplitude Levels

Fig. 3. Key elements of averager

Fig. 4. Averager block diagram
Fig. 5. Scanner parameters

\[ V \text{ in/sec} = \text{scan velocity} \]

\[ L \text{ mil/inch} = \text{grid spacing} \]

\[ R \text{ pulses/millisecond} = \text{pulse repetition rate} \]

\[ \text{MAX number of averages per grid} = \frac{F_0}{V} \]

Fig. 6. Averager output

**GENERAL**

\[ E_0 = E_{IN} \left[ 1 + W + W^2 + W^3 + \cdots \right] \]

**STEADY STATE**

\[ E_0 = E_{IN} \cdot \left[ \frac{1}{1 - W} \right] \quad W < 1 \]

**E_0 = output voltage**

**E_{IN} = input voltage**

**W = weighing factor**

**In selecting W must consider trade off,**

- *Maximize signal/noise (W large)*
- *Have an acceptable decay of previous bin value 10 - 20 db. (W small)*

Fig. 7. Averager operation

**The improvement in S/N:**

\[ \gamma_N = 10 \log_{10} \left[ \frac{1 + W}{1 - W} \right] \quad \text{DB} \]

**The average output will have the previous bin signal down:**

\[ \gamma_N = 20N \log_{10} W \quad \text{DB} \]

**WHERE:**

- \( W = \text{weighting function} \)
- \( N = \text{number of averages/grid} \)

Fig. 8. Averager performance
**Objective:** To verify the averager provides a signal to noise gain for ultrasonic type signals and that the CCD time control can correct for summing amplifier, feedback amplifier, and pulser trigger delays.

**Procedure:**
- Adjust the repetition rate to 1 kHz.
- Center the 50 mV signal pulse in the CCD storage and adjust the pulse width to match an actual transducer pulse width.
- Increase the number of counts which in turn advances data in the CCD and corrects for the various delays mentioned above. Increase counts until feedback time phased with input.
- Fine tune feedback alignment by selecting appropriate 1/4 clock.
- Adjust the feedback weighting factor (W) until the output signal is \(6 \times\) input.
- Add noise to signal and measure signal to noise at input and output.

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**Fig. 9.** CCD clock control

**Objective:** To verify the averager provides a signal to noise gain.

**Procedure:**
- Adjust the oscillator input amplitude to 50 mV (noise free condition).
- Adjust the oscillator frequency to the transducer center frequency and fine tune until output peaks. (CCD free running phase aligning feedback with output).
- Adjust the feedback weighting factor (W) until the output is \(6 \times\) input.
- Add noise to signal and measure signal to noise at input and output.
- Since the CCD is free running, the averager feedback timing is not being tested.

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**Fig. 10.** Simulation test #1

**Fig. 11.** Simulation test #1

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**Fig. 12.** Simulation test #2

**Fig. 13.** Simulation test #2

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**Fig. 14.** Possible benefits of averager
ALL RESULTS ARE BASED ON AN EFFECTIVE CCD CLOCKING OF 33.2 MHZ. AT 25 MHZ THE 1/4 FINE TUNE COUNT CONTROL IS NECESSARY TO ALIGN FEEDBACK WITH INPUT SIGNAL FOR 3.5 MHZ TRANSDUCER. THIS FINE TUNE CONTROL IS BEING CONSTRUCTED.

A SIGNAL INCREASE OF 6 TO 8 HAS BEEN ACHIEVED FOR A 1 MHZ TRANSDUCER.

A SIGNAL INCREASE OF 4 TO 6 HAS BEEN ACHIEVED FOR A 3.5 MHZ TRANSDUCER.

FILTER COMPENSATION IS NECESSARY FOR THE 3.5 MHZ TRANSDUCER.

A NOTCH FILTER CENTERED AT CLOCK FREQUENCY HAS CAUSED CLOSED LOOP OSCILLATIONS AND HAS BEEN REMOVED.

OLD CCD HAS 8 EQUALLY SPACED SPIKES ON OUTPUT WHICH INCREASE WITH AVERAGING. NEW, REDESIGNED CCD HAS NOT BEEN TESTED IN AVERAGER, BUT SHOULD ELIMINATE THE PROBLEM SINCE SPIKES 20 db LOWER.

THE CCD COUNTER HAD A PROBLEM WHICH HAS BEEN CORRECTED. ALTHOUGH THE PULSER TRIGGER IS ASYNCHRONOUS TO THE CLOCK, CIRCUITRY MUST BE PROVIDED TO INSURE THE FIRST CLOCK PULSE TO THE COUNTER IS A FULL CLOCK PULSE OR ERRONEOUS COUNTS WILL OCCUR.

CIRCUIT OSCILLATIONS OCCUR WHEN SIGNAL INCREASES GREATER THAN 6 TO 8 ARE ATTEMPTED. THIS INSTABILITY IS UNDER INVESTIGATION.

DATA IS NOT CLOCKED THROUGH THE CCD UNTIL AFTER THE MAIN PULSE HAS OCCURRED. DATA HAS BEEN CLOCKED THROUGH INCLUDING THE MAIN PULSE BUT THIS MAY IMPACT STABILITY.

BECAUSE OF THE FAST RISE TIME OF THE MAIN PULSE, THERE IS SOME SPIKE LEAKAGE PAST THE DIODE PROTECTION.

THE PULSER TRIGGER MUST OCCUR AT THE SAME INSTANT IN TIME WITH RESPECT TO THE MAIN PULSE. IN ONE ULTRASONIC UNIT THE TRIGGER PULSE MOVED IN TIME WHEN THE PULSER AMPLITUDE WAS INCREASED. THIS CAUSED MISALIGNMENT IN THE AVERAGER.


Fig. 15. Averager results as of 7/14/78