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

0 INPUT PROTECTED - ±450 VOLTS PULSER
0 SIGNAL BANDWIDTH - 5 MHZ
0 FILTERING - MATCHED TO 3.5 MHZ TRANSDUCER
0 MAXIMUM OF 36 µSEC STORAGE
0 PULSE REPETITION RATE - 1 MHZ
0 TTL TRIGGER INPUT
0 LINEAR SIGNAL RANGE - ± 500 MV.
0 EFFECTIVE INTERNAL CLOCKING RATE - 25 MHZ
0 DIMENSIONS - 5" x 6" x 10"
0 POWER - 115 VOLTS 60N
0 INTERNAL POWER:

- CCD - 20 VOLTS
- DIGITAL CONTROL - 5 VOLTS
- ANALOG - ± 15 VOLTS

Fig. 1. Real time CCD averager for ultrasonic application

0 DECAY OF CCD SIGNAL/NOISE INCREASE
0 TIME DELAY AND PHASE SHIFT OF AVERAGER LOOP
0 FILTERING OF CCD CLOCK AND SIGNAL
0 RECEIVED AMPLITUDE LEVELS

Fig. 2. Design considerations

Fig. 3. Key elements of averager

Fig. 4. Averager block diagram
V in/sec = scan velocity
L mil/inch = grid spacing
R pulses/millisecond = pulse repetition rate
Max number of averages per grid = \( \frac{P}{V} \)

**Fig. 5.** Scanner parameters

### General

\[ E_0 = E_{IN} \left[ 1 + w + w^2 + w^3 + \ldots + w^n \right] \]

Present Bin

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

\( E_0 \) = output voltage

\( E_{IN} \) = input voltage

\( w \) = weighting 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. 6.** Averager output

**Fig. 7.** Averager operation

The improvement in S/N:

\[ T_N = 10 \log_{10} \left( \frac{1 - w}{1 - w + w^2} \right) \text{ dB} \]

The averager output will have the previous bin signal down:

\[ G_N = 20 \log_{10} w \text{ dB} \]

Where: \( w \) = weighting function

\( N \) = number of averages/grid

**Fig. 8.** Averager performance
OBJECTIVE - TO VERIFY THE AVERAGER PROVIDES A SIGNAL TO NOISE GAIN.

PROCEDURE -
1. Adjust the repetition rate to 1 kHz.
2. Center the 50 mV signal pulse in the CCD storage and adjust the pulse width to match an actual transducer pulse width.
3. 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.
4. Fine tune feedback alignment by selecting appropriate 1/4 clock.
5. Adjust the feedback weighting factor (W) until the output signal is 6 x input.
6. Add noise to signal and measure signal to noise at input and output.

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

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

- Improve signal detection when low level signals are encountered.
- When transducer decoupling occurs improve possibility of signal reception in a grid by taking multiple samples.
- By taking spatially moving averages in a grid decorrelate grain noise.

**Fig. 14. Possible benefits of averager**
ALL RESULTS ARE BASED ON AN EFFECTIVE CCD CLOCKING OF 33.2 MHZ. AT 25 MHZ THE 3/4 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. NOW, 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 3 microsec. 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