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THE DIGITAL ULTRASONIC TEST UNIT FOR AUTOMATIC EQUIPMENT

LE DIGITAL ULTRASONORE TEST UNITÉ POUR AUTOMATIQUE ÉQUIPMENT

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SUMMARY: Operations and features of the ultrasonic test unit adopted the digital data processing techniques and this unit is used for a few hundred multi-channel automatic ultrasonic test equipment.

RESUME : operations et features de la ultrasonore test unité adoptée les digital procédaut techniques, et quelque centa multi-canal automatique ultrasonore test équipment.

I. INTRODUCTION

Today, a great many structures are built of steel, and if there happens to be an accident in these structures, that would effect the activities of the enterprises and the communicaties. So the society requires strictly their safety.

Therefore, customer's requirements of quality of steel pipe, plate, etc. have become strictly with the social recognition of the safety. Non destructive tests to inspect the quality of these products have become a matter of course, and automatic ultrasonic testing method is adopted from many non destructive testing methods, to test widely and speedily and to lessen the cost up by non destructive testing. But data processing, calibrating, checking, etc. of the automatic ultrasonic test equipment are very heavy loads for operators in case of a large scale, and that would do wrong to the operation and the scale of the equipment.

While, there are strong requirements for a large scale of automatic ultrasonic test equipment in steel makers, today. The equipment for these requirements should have the following functions; automatic testing, automatic test data processing (including compilation of data), automatic calibration and check of the equipment, and institution of test region, test sensitivity, characteristics of Distance Amplitude Correction (DAC) and the like, which should be carried out freely by electronic order from a process computer.

We have developed a large scale of automatic ultrasonic test equipment which satisfies those requirements above mentioned. The digital ultrasonic test unit is a main constituent unit.

II. DIGITAL ULTRASONIC TEST UNIT

Automatic ultrasonic test equipment consists of probes, ultrasonic test units, a data processing device and a mechanism of test material handling and probe supporting, etc. The ultrasonic test units are one of the main constituents in these. Today, in many case, the test conditions (for examples; test region, test sesitivity, etc.) of the ultrasonic test devices of automatic equipment are set and controlled by manual operation, and automatic calibrations and selfcheck are poor, as the test signal is detected and filtered, many useful informations in test wave forms are eliminated, and the test informations are only at the echo height in test region. In this digital test unit, the following countermeasures are adopted to improve the above mentioned problems.

(1) To obtain the authentic test informations, a test signal (analogue signal) is converted into a digital signal in the test unit leaving RF (Radio Frequency) wave form as it is. By this method, high amplitude stages of a receiving amplifier becomes unless and its dynamic characteristics are improved.
(2) Time sharing multi-channel method is not used and one test unit is coupled to one probe. By this means, merits are obtained as following.
(a) Test speed gets higher, and S/N (signal to noise ratio) of test signal is improved by auto-correlation method.
(b) The acoustic coupling conditions and characteristics of a probe are to be corrected automatically.
(c) A trouble of one unit does not lead to a grover trouble in case of a multi-channel equipment.
(d) As the characteristics of each probe are checked automatically, the change of its characteristics is found easily and probe maintenance is easy.

The reasons of being able to adopt them are by coming out CMOS IC (integrated circuit) development of digital technique with high responce, reduction of power consumption, improvement of reliability of active elements, high integration of parts and reduction of parts cost, etc.

As a large scale of automatic ultrasonic test equipment consists of a few hundreds test units, the control is no longer achieved by manual operations.

Therefore, the following functions are indispensable for the unit.

(1) Automatic tracking of surface echo

In many cases of automatic equipments, probes are not directly contracted to test materials using water (couplant), and a little charge of path length of probes-test material is enlarged four times as large as in steel (test material). So, always in testing, surface echo must be tracked automatically to maintain precisely test region in test material.

In the test unit, only Sc (an echo generating at the boundary of water-steel; see Figure 1;) is picked from two echoes generating at the boundaries of wadge (probe) -water (couplant) and water-steel (test material) by Tracking A/D converter and Sc gets to be PROBE INDEX.

(2) Automatic set of test sensitivity

The level of calibration signals from standard flaw in the test block is compared with the standard level from the external controller, and electronic digital attenuater in receiving amplifier operates to equalize the both levels automatically, and amplifier's sensitivity is set to satisfy the given test condition.

By this function, test sensitivity of each unit is to be performed the control synchronously and quantitatively.

(3) Automatic DAC

The slope of DAC is changed by the control signal from external controller and calibration/check signal generating in the test unit, to correct the variety of the echo height of flaw with the distance from test surface, which is due to the characteristics of distance-amplitude of the probe and attenuation in test material. By this function, the evaliation of the flaw is not effected by the distance.

(4) Automatic selfcheck and calibration

Signals of automatic selfcheck and calibration are generated by delaying and attenuating the transmitting pulses. By external control signal, selfcheck and calibration of each part are carried out by these pulses.

Calibration and check items are as following:

(1) Test sensitivity
(2) DAC characteristics
(3) Test region

The results of calibration and check are displayed on monitor panel, and the same time these information are supplied to computer to record and compilate as maintenance data. If these results are over preset threshold levels, channel number of the fault unit and fault position in the unit are displayed on monitor panel for easy maintenance.

III. OPERATION AND FEATURES OF DIGITAL ULTRASONIC TEST UNIT

III-1 OPERATION

Operations of the unit consists of two phase as test phase and calibration/

check phase.

Block diagram waveforms and time sequence of the unit are shown in Figure 1. The operation is explaned in the case of steel plate testing and double cristal probe technique, recently this technique is used as steel plate testing.

III-1-(1) TEST PHASE

Electric pulses from a transmitter are supplied to the probe. These pulses are converted into ultrasonic pulses in the probe and emitted in the test material. Ultrasonic pulses are reflected at each boundary of transducer-wedge, wedge-water, water-steel, flaw (if exists) and bottom. These reflected pulses train is able to draw as single probe echo waveforms (see waveform (3) in Figure 1).

Surface echo Sc only is discriminated from this pulse train by tracking A/D converter, which possesses the function of tracking location of maximum echo height in surface echo gate, by comparing with sampled adjacent pulses in A/D converting. Sc is the start trigger of GATES (see Figure 1). The gates of pre-decided test region in steel (test material) are gated by three control signal of F echo gate length, B echo gate length and DAC starting position and 0.5mm clock (this clock is changed to distance in steel by longitudial wave velocity = 5900m/s) in external sound velocity controller).

Next, test signals from double cristal probe are supplied into receiving amplifier, and these signals are amplified to pre-decided level in accordance with pre-calibrated amplifier characteristics (sensitivity and DAC). In ATT/Check/DAC controller, acoustic coupling check is carried out by comparing with Bs echo level and preset level. Amplified test signals are supplied to echo height A/D converter. If flaw echoes exist in F echo gate, these echoes are converted into digital signals which are supplied into the computer through I/O unit.

As this A/D converter is designed to operate a fixed signal responce concerning with beam width of probe and relative speed of flaw motion, it does not respond the input as sharp pulse noise. The distance signal of the nearest echo from a start point of F echo gate is generated in ATT/Check/DAC controller and the distance signal of maximum echo in F echo gate from start point in the gate is generated in echo height A/D converter and these distance signals are supplied to echo distance A/D converter and are converted digital distance signal by above mentioned 0.5mm clock in steel.

Digital distance signals are also supplied in to the computer through external I/O unit.

III-1 (2) CALIBRATION/CHECK PHASE

There are two modes in this phase, one is calibration/check by the signal generated in the unit, and another is by external signal supplied from reference test block. In case of calibration/check by internal signals, input terminal of receiving amplifier is changed in to check terminal by external control signal (RIS) and supplied pulse signals proportional to transmitter output, and these signals are compared with preset standard signal in ATT/Check/DAC controller. ATT/Check/DAC controller operates the order of electronic attenuator in receiving amplifier to equalize the both signal levels and it operates the order to DAC slope controller in receiving amplifier to equalize nearly echo height in F gate.

In case of external calibration/check signals, input terminal of receiving amplifier is set to "TEST" terminal and calibration/check of standard sensitivity and DAC slope are carried out as well as in the case above mentioned.

Gate/DAC timing generater outputs the clocks of gate start point B and F gate length and DAC start point supplies them in to each circuit in the unit. These clocks and DAC slope signal are converted into the digital signal by Gate/DAC A/D converter. Digital test output signal, the nearest echo distance signal, the maximum echo distance signal, gate signals and DAC slope signal are supplied to the computer and the monitor panel as monitoring and maintenance data, through monitor output selector controlled by external order signals.

III-2 FEATURES

Table 1 shows Main specifications of the unit, and Figure 2 shows the

linearity of receiving amplifier and Figure 3 shows DAC characteristics of the unit.

IV. CONCLUSIONS

The units are used through various examinations in the large scale of automatic ultrasonic test equipment consisted of a few hundred channels.

The following functions of the unit may be applied to today's conventional ultrasonic flaw detector.

(1) Automatic reading of the nearest echo distance and echo height in test region without fixing probe.
(2) Automatic reading of the maximum echo distance and echo height in test region without fixing probe.
(3) Simple operation of set of test sensitivity by means of automatic attenuator.
(4) DAC of small flaw using multiple bottom echoes by automatic DAC.

As conventional flaw detector, (1)-(4) above items are very important, difficult and foundmental operation carried out by test engineer observing image on CRT.

Therefore, we expect that the ultrasonic flaw detector with above mentioned functions and digital displayer (CRT will require as monitor, too.) will considerably save ultrasonic test works.

Today, the digital technique develops remarkably and we can get easily various large scale of digital integrated circuit. Under these circumstances, we expect that digital techniques are adopted in the ultrasonic test field more widely and many merits of ultrasonic test will be more effective.

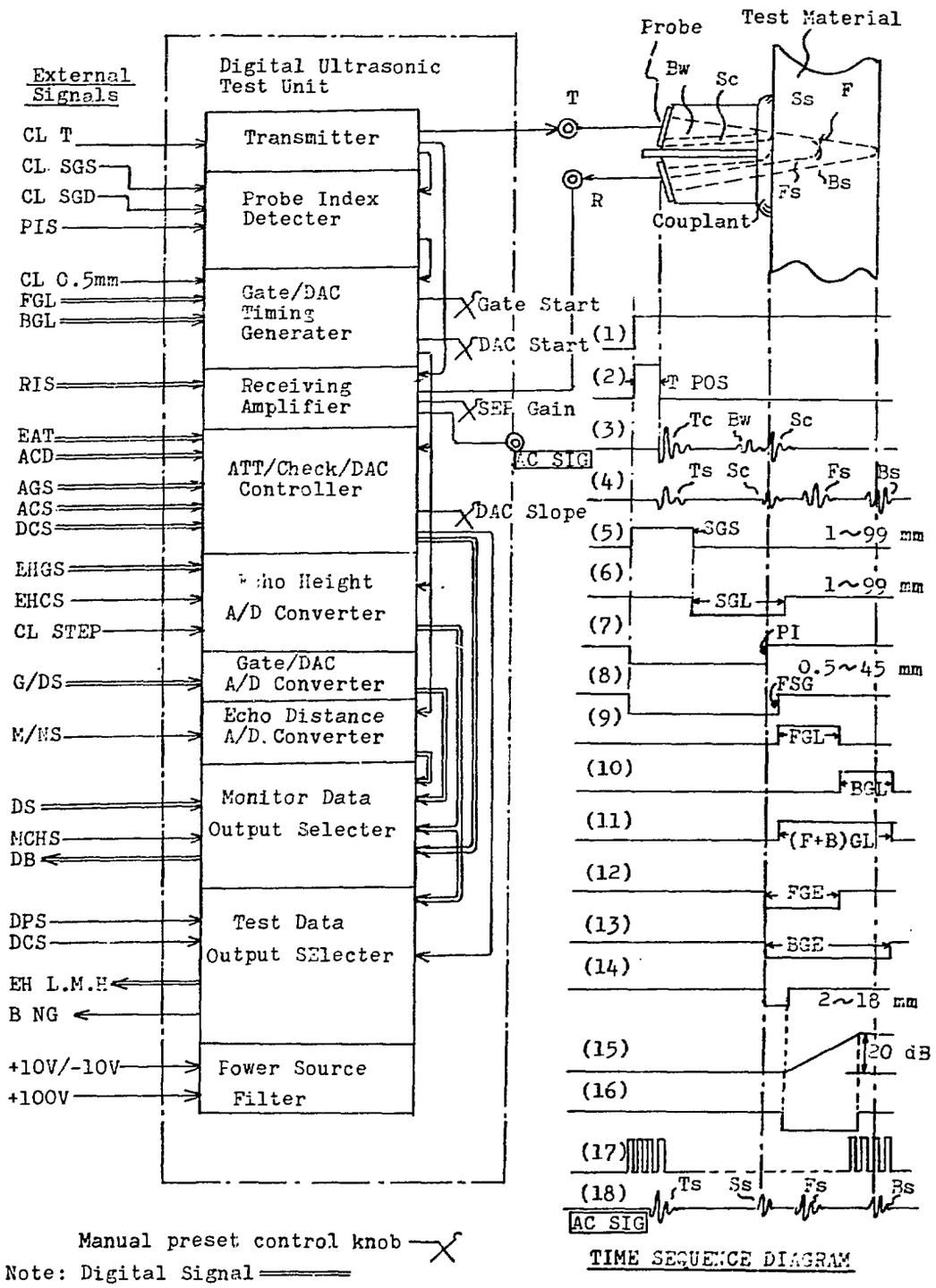

Figure 1 Block diagram and time sequence diagram of the unit

EXTERNAL SIGNAL

SYMBOLS	MEANS
CL T	Transmitting clock
CL SGS	Surface echo gate clock
CL SGL	Surface echo gate length clock
PIS	Probe index select signal
CL 0.5mm	Velocity/Distance clock
FGL	Flaw echo gate length signal
BGL	Bottom echo gate length signal
RIS	Receiving amplifier input select signal
EAT	External ATT control signal
ACD	ATT/Check/DAC comparison level
AGS	ACD gate select signal
ACS	ATT control mode select signal
DCS	DAC control mode select signal
EHGS	Echo height gate select signal
EHCS	Echo height A/D control mode select signal
CL STEP	Echo height A/D step clock
G/DS	Gate/DAC distance monitor output select signal
M/NS	Maximum echo height/nearest echo height, echo distance monitor output select signal
DS	Monitor output mode select signal
MCHS	Monitor unit channel select signal
DB	Monitor test data output select signal
DPS	Test data output select signal
DCS	Test data channel select signal
EH.LMH	Test data output echo height
B NG	Bottom echo no good signal

TIME SEQUENCE DIAGRAM

NOMUBER	CLOCK AND SIGNAL
1	Main clock
2	CL T: Transmitting clock
3	Common signal input: single cristal
4	Separate signal input: double cristal
5	CL SGS: Surface echo gate start clock
6	CL SGL: Surface echo gate length clock
7	Probe index clock
8	Flaw echo gate start clock
9	Flaw echo gate length clock
10	Bottom echo gate length clock
11	Flaw echo+bottom echo gate length clock
12	Flaw echo gate end clock
13	Bottom echo gate end clock
14	DAC start clock
15	Receiving amplifier gain
16	DAC slope clock
17	CL 0.5mm: Velocity/distance clock
18	Receiving amplifier AC output for monitoring

Items	Major specifications
Transmitter	
1. Output	100Vp-p at 50 ohm load
2. Frequency	5MHz±0.3MHz
3. Pulse repeating frequency	5~2000Hz
Receiving amplifier	
4. Maximum amplification gain	66dB±2dB
5. DAC gain dynamic range	17dB or more
6. DAC slope adjustable step	Manual:10 steps by DAC slope knob Automatic:16 steps by DAC Cal operation
7. External ATT operation	1.0dB+0.2dB steps between 0~15dB by external control signal
8. Output (digital)	(1)Dynamic range: 5~250% (2)Analoge linearity: 0.5dB±2% (3)Digital step error: 1% or less
9. ATT/Check/DAC level	5~200% (1% step variable)
10. Nearest echo distance operation	Measureable range: 0.5mm steps between 1.0mm~60mm in steel
11. Maximum echo distance operation	Measureable range: 0.5mm steps between 1.0mm~60mm in steel
Gate/DAC timing	
12. Flaw echo gate start operation	Free setting 0.5mm steps between 2.0mm~4.0mm from PI (in steel)
13. Flaw echo gate length operation	Free setting 0.5mm steps between 2.0mm~60mm (in steel)
14. Bottom echo gate length operation	Free setting 2.0mm steps between 2.0mm~60mm (in steel)
15. DAC start operation	Free setting 2.0mm steps between 4.0mm~16mm (in steel)
16. Power consumption	+10V±0.3V 0.1A or less -10V±0.3V 0.08A or less
17. Size and weight	Approx $150^{h}X70^{w}X250^{l}$ mm Approx 1.2Kg

Table 1 Major specifications of digital ultrasonic test unit

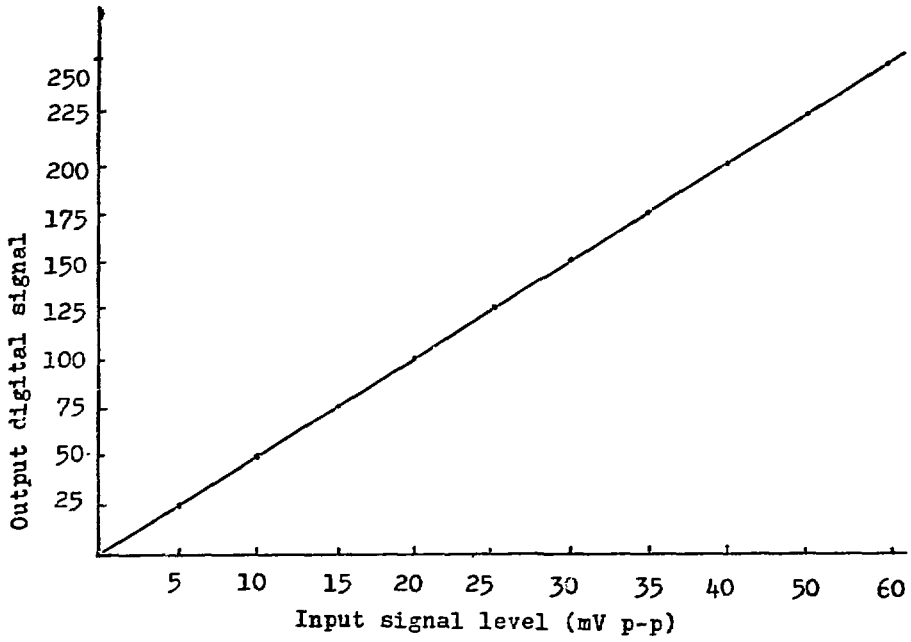

Figure 2 The linearity of receiving amplifier

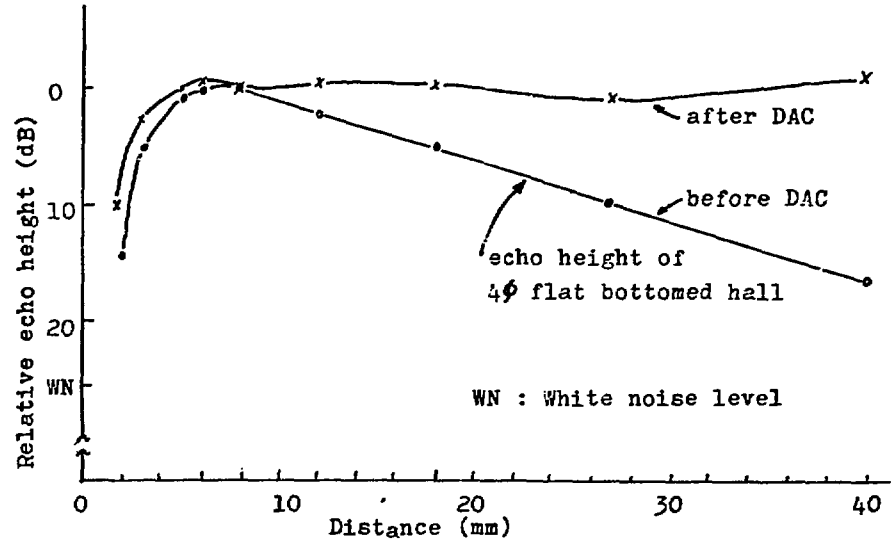

Figure 3 DAC characteristics of the unit