
**Non-destructive testing —
Characterization and verification of
ultrasonic test equipment —**

**Part 1:
Instruments**

*Essais non destructifs — Caractérisation et vérification de
l'appareillage de contrôle par ultrasons —*

Partie 1: Appareils



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 22232 series can be found on the ISO website.

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Non-destructive testing — Characterization and verification of ultrasonic test equipment —

Part 1: Instruments

1 Scope

This document specifies methods and acceptance criteria within the frequency range of 0,5 MHz to 15 MHz, for assessing the electrical performance of digital ultrasonic instruments for pulse operation using A-scan display, for manual ultrasonic non-destructive testing with single- or dual-transducer probes. This document is also applicable for multi-channel instruments. This document can partly be applicable to ultrasonic instruments in automated systems, but other tests can be needed to ensure satisfactory performance.

This document excludes ultrasonic instruments for continuous waves.

This document also excludes ultrasonic phased array instruments, see e.g. ISO 18563-1. If a phased array instrument has dedicated connectors for single- or dual-transducer probes this document is applicable for these channels.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5577, *Non-destructive testing — Ultrasonic testing — Vocabulary*

ISO/IEC 17050-1, *Conformity assessment — Supplier's declaration of conformity — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5577 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

analogue output

output from the ultrasonic instrument which gives a d.c. voltage nominally proportional to the amplitude of the largest received signal within a monitor gate

3.2

cross talk during transmission

amount of signal transfer from the transmitter output to the receiver input during the transmission pulse, with the ultrasonic instrument set for separate transmitter-receiver operation (dual-transducer probe)

3.3

dead time after transmitter pulse

time interval following the start of the transmitter pulse during which the amplifier is unable to respond to incoming signals, when using the pulse-echo technique, because of saturation by the transmitter pulse

3.4

digital output

output from the ultrasonic instrument which gives a low or high value depending if a signal is below or above a monitor gate threshold

3.5

digitisation sampling error

error introduced into the displayed amplitude of an input signal by the periodic nature of measurements taken by an analogue-to-digital converter

3.6

equivalent input noise

measure of the electronic noise level observed on the ultrasonic instrument screen, and defined by the input signal level, measured at the receiver input terminals, that would give the same level on the screen if the amplifier itself were noiseless

3.7

external attenuator

standard attenuator calibrated to a traceable source used to test the ultrasonic instrument

3.8

fall time

<analogue output> time it takes the proportional gate output to fall from 90 % to 10 % of its peak value

3.9

switched monitor gate signal hold time

time for which the switched output from a monitor gate remains above 50 % of its maximum output following a signal in the monitor gate which is above the threshold

3.10

hold time

<analogue output> time for which the *analogue output* (3.1) is above 50 % of its maximum output following a signal in the monitor gate

3.11

linearity of analogue output

measure of how close the voltage output from the proportional gate is to being directly proportional to the input signal amplitude

3.12

mid-gain position

ultrasonic instrument gain setting which is half way between the maximum and minimum gains

EXAMPLE For an ultrasonic instrument with a maximum gain of 100 dB and a minimum gain of 0 dB, the mid-gain position would be 50 dB.

Note 1 to entry: Mid-gain position is measured in decibels.

3.13

receiver input impedance

characterisation of the internal impedance of the receiver as a parallel resistance and capacitance

3.14

response time

time over which a signal has to be detected by an ultrasonic instrument before it is displayed at 90 % of its peak amplitude

3.15**temporal resolution**

minimum time interval over which two pulses are resolved by a drop in amplitude of 6 dB

3.16**switching hysteresis**

difference in amplitude between the signal which turns on and the signal which turns off a monitor gate

4 Symbols

Symbol	Unit	Meaning
A_o, A_n	dB	Attenuator settings used during tests
$C_{\max}$	pF	Parallel capacity of receiver at the maximum gain
$C_{\min}$	pF	Parallel capacity of receiver at the minimum gain
D_s	dB	Cross talk during transmission
Δf_g	Hz	Frequency bandwidth measured at the proportional gate output
f_{go}	Hz	Centre frequency measured at the proportional gate output
f_{gu}	Hz	Upper frequency limit at -3 dB, measured at the proportional gate output
f_{gl}	Hz	Lower frequency limit at -3 dB, measured at the proportional gate output
$f_{g\max}$	Hz	Frequency with the maximum amplitude in the frequency spectrum measured at the proportional gate output
f_0	Hz	Centre frequency
f_u	Hz	Upper frequency limit at -3 dB
f_l	Hz	Lower frequency limit at -3 dB
$f_{\max}$	Hz	Frequency with the maximum amplitude in the frequency spectrum
Δf	Hz	Frequency bandwidth
G_D	dB	Dynamic range
$I_{\max}$	A	Amplitude of the maximum current that can be driven by the proportional gate output
N	—	Number of measurements taken
n_{ein}	nV / $\sqrt{\text{Hz}}$	Equivalent input noise
R_l	Ω	Termination resistor
$R_{\max}$	Ω	Input resistance of receiver at the maximum gain
$R_{\min}$	Ω	Input resistance of receiver at the minimum gain
S	dB	Attenuator setting
ΔT	s	Time increment
t_A	s	Temporal resolution
t_d	s	Pulse duration
T_{final}	s	Time to the end of a distance-amplitude curve
T_0	s	Time to the start of a distance-amplitude curve
t_m	s	Measured rise time
t_r	s	Transmitter pulse rise time from an amplitude of 10 % to 90 % of the peak amplitude
t_s	s	Oscilloscope rise time
V_E	V	Input voltage at the receiver
V_{ein}	V	Equivalent input noise voltage
V_{in}	V	Input voltage
V_l	V	Proportional gate output voltage with load resistor
$V_{\max}$	V	Maximum input voltage of the receiver
$V_{\min}$	V	Minimum input voltage of the receiver

Symbol	Unit	Meaning
V_o	V	Proportional gate output voltage with no load resistor
V_{50}	V	Voltage amplitude of the transmitter pulse with a 50 Ω loading of the transmitter
V_{75}	Ω	Voltage amplitude of the transmitter pulse with a 75 Ω loading of the transmitter
Z_o	Ω	Output impedance of transmitter
Z_A	Ω	Output impedance of analogue output

5 General requirements of conformity

An ultrasonic instrument complies with this document if it fulfils all of the following requirements:

- the ultrasonic instrument shall comply with [Clause 7](#) within the frequency range of 0,5 MHz to 15 MHz;
- a declaration of conformity according to ISO/IEC 17050-1 shall be available, issued by either the manufacturer operating a certified quality management system (e.g. in accordance with ISO 9001) or by an organization operating an accredited test laboratory (e.g. in accordance with ISO/IEC 17025);
- the ultrasonic instrument shall be clearly marked to identify the manufacturer, and carry a unique serial number or show a permanent reference number from which information can be traced to the data sheet;
- a manufacturer's technical specification corresponding to the ultrasonic instrument shall be available, which defines the performance criteria in accordance with [Clause 6](#).

6 Manufacturer's technical specification for ultrasonic instruments

The manufacturer's technical specification for an ultrasonic instrument shall contain, as a minimum, the information listed in [Table 1](#). The actual values quoted for the parameters listed in this clause shall be the results obtained from the tests described in [Clause 7](#), with tolerances given as indicated.

Where applicable, these details should also include sampling rates used, effect of pulse repetition frequency or display range on the sampling rate and response time. In addition, the principles of any algorithm used to process data for display shall be described and the version of any software installed shall be quoted.

Table 1 — Technical characteristics to be shown in the instrument's technical specification

Information	Type of information	Remarks
General features		
Size	OI	Width (mm) × height (mm) × depth (mm)
Weight	OI	At an operational stage including all batteries
Type(s) of power supply	OI	—
Type(s) of instrument sockets	OI	—
Battery operational time	M	At fully charged new batteries
Number and type of batteries	OI	—
Stability against temperature	M	—
Key		
M measurement		
OI other information		

Table 1 (continued)

Information	Type of information	Remarks
Stability after warm-up time	M	—
Stability against voltage variations	M	—
Temperature and voltage (mains and/or batteries) ranges in which the instrument operates in accordance with the technical specification (operation and storage)	OI	When a warm-up time is necessary, its duration shall be stated
Form of indication given when a low battery voltage takes the ultrasonic instrument performance outside of the specification	OI	—
Pulse repetition frequencies (PRFs)	M	Minimum and maximum values
Maximum power consumption	OI	W
Protection grade	OI	—
Environment	OI	For example: restriction of hazardous substances (RoHS), explosive atmosphere (ATEX), vibration, humidity
Multi-channel configuration	OI	Number of channels controlled simultaneously (parallel operation) and number of available channels (multiplexed operation)
Extension of the number of channels by interconnection of instruments	OI	—
Available measurement units	OI	For example: mm, inches, %, dB, V
Display		
Screen size and resolution	OI	—
Range of sound velocities	OI	—
Time base delay range	OI	—
List of available views	OI	—
Screen refresh rate for A-scan presentations	OI	—
Maximum digitization frequency without processing	OI	—
Digitization frequency with processing	OI	For example: interpolation
Digitizer vertical resolution	OI	In bits
Highest digitized frequency	OI	—
Time base deviation	M	—
Response time	M	—
Inputs/outputs		
Signal unrectified output (i.e. radio frequency, RF) and/or rectified available on the output socket	OI	—
Number and characteristics of logic and analogue control outputs	OI	Including the wiring diagram
Number and characteristics of encoder inputs	OI	Including the wiring diagram
Power input	OI	AC, DC, voltage range, power (W)
Key		
M measurement		
OI other information		

Table 1 (continued)

Information	Type of information	Remarks
Available power supply for external devices	OI	Voltage, power
Synchronization input/output	OI	—
Transmitter		
Shape of transmitter pulse and, where applicable, polarity	OI	i.e. rectangular, unipolar, bipolar, arbitrary pulse
Transmitter voltage, pulse rise time, fall time and duration	M	—
Output impedance	M	—
Possibility to apply different voltages on each channel	OI	—
Maximum power available per transmitter	OI	—
Receiver		
Characteristics of the gain control, i.e. range in decibels, value of increments	OI	—
Characteristics of the logarithmic amplifier	OI	—
Input voltage at full screen height (FSH)	OI	—
Maximum input voltage	M	$V_{\max}$ measured in 8.9.4.1
Linearity of vertical display	M	—
Frequency response	M	—
Dead time after transmitter pulse	M	—
Equivalent input noise	M	$\frac{nV}{\sqrt{Hz}}$
Dynamic range	M	—
Input impedance	M	—
Time-corrected gain (TCG)	M	—
Possibility to apply different gain values on each channel	OI	—
Cross talk between transmitter and receiver	M	—
Gain linearity	M	—
Data acquisition		
Transfer rate between the instruments and the external storage unit	OI	Including type of interface
Maximum number of A-scans stored per second	OI	A-scan characteristics shall be stated
Maximum number of C-scans stored per second	OI	C-scan characteristics shall be stated
Maximum number of samples per A-scan	OI	—
Gates		
Number of gates	OI	—
Threshold operation	OI	For example: coincidence or anti-coincidence
Measurement mode	OI	For example: threshold, max amplitude, zero crossing
Key		
M measurement		
OI other information		

Table 1 (continued)

Information	Type of information	Remarks
Synchronisation of gates	OI	For example: transmission pulse, first echo
Characteristics of gates	OI	Threshold, position, duration
Resolution of measurements	OI	—
Trigger of alarms	OI	For example: number of sequences before an alarm is triggered
Linearity of the amplitude in the gate	M	—
Linearity of the time of flight in the gate	M	—
Impedance of analogue output	M	—
Linearity of analogue output	M	—
Influence of the measurement signal position in the gate of the analogue output	M	—
Rise, fall and hold time of the analogue gate output	M	—
Threshold of the alarm gate output	M	—
Switching hysteresis of the alarm gate output	M	—
Hold time of the alarm gate output	M	—
Signal processing		
Processing features	OI	For example: averaging, Fast Fourier Transform (FFT), rectification, envelope, compression, dimensional measurements
Key M measurement OI other information		

7 Performance requirements for ultrasonic instruments

The ultrasonic instrument shall be subjected to all the tests described below. For multi-channel instruments, parallel or multiplexed, each channel to be used shall be tested. The test results shall meet or exceed the stated requirement in every case. The results shall be recorded and stored for verification.

- a) Group 1 tests: to be performed at manufacture on a representative sample of the same type of ultrasonic instruments produced.
- b) Group 2 tests: to be performed on every ultrasonic instrument:
 - 1) by the manufacturer or an agent, prior to the supply of the ultrasonic instrument (baseline measurements);
 - 2) by the manufacturer, the owner or a laboratory, at twelve months intervals to verify the performance of the ultrasonic instrument during its lifetime;
 - 3) following the repair of the ultrasonic instrument.

By agreement between the parties involved, these group 2 tests may be supplemented with additional tests from group 1.

For ultrasonic instruments marketed before the introduction of this document continuing compliance with this document shall be demonstrated by performing the group 2 (periodic) tests every twelve months.

Following repair, all parameters which may have been influenced by the repair shall be checked using the appropriate group 1 or group 2 tests.

Table 2 summarises the tests to be performed on ultrasonic instruments. For ultrasonic instruments with a logarithmic amplifier, Annex A shall be taken into account.

Table 2 — List of tests for ultrasonic instruments

	Group 1 Manufacturer's tests	Group 2 Baseline, periodic and repair tests
	Subclause	Subclause
Physical state and external aspects	9.2	9.2
Battery operational time	8.2	
Stability		
Stability after warm-up time	8.3	
Stability against temperature	8.4	
Stability against voltage variation	8.5	
Time base deviation	8.6	
Transmitter pulse		
Pulse repetition frequency	8.7.2	
Effective output impedance	8.7.3	
Transmitter voltage, pulse rise time and duration	9.3	9.3
Receiver		
Cross talk from transmitter to receiver during transmission	8.8.2	
Dead time after transmitter pulse	8.8.3	
Dynamic range	8.8.4	
Receiver input impedance	8.8.5	
Time-corrected gain (TCG)	8.8.6	
Frequency response	9.4.2	9.4.2
Noise	9.4.3	9.4.3
Gain linearity	9.4.4	9.4.4
Vertical linearity	9.4.5	9.4.5
Gates		
Gates with value output		
Linearity of amplitude in the gate	8.9.2.1	
Linearity of time of flight in the gate	8.9.2.2	
Gates with analogue output		
Impedance of the analogue output	8.9.3.1	
Linearity of the analogue output	8.9.3.2	
Influence of signal position within gate	8.9.3.3	
Rise time, fall time, and hold time of the analogue output	8.9.3.4	
Gates with alarm output		
Response threshold and switching hysteresis	8.9.4.2	
Hold time of the gate alarm	8.9.4.3	
Digital processing		
Highest digitized frequency	8.10.1	
Response time of digital ultrasonic instruments	8.11	

8 Group 1 tests

8.1 Equipment required for group 1 tests

The items of equipment essential to perform group 1 tests on ultrasonic instruments are as follows:

- a) either:
 - 1) an oscilloscope with a minimum bandwidth of 100 MHz and a spectrum analyser with a 40 MHz bandwidth at least; or
 - 2) a digital oscilloscope with a minimum bandwidth of 100 MHz and the capability to calculate Fast Fourier Transforms;
- b) 50 Ω and 75 Ω resistors, with a tolerance of ± 1 %;
- c) a standard 50 Ω attenuator with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency up to 15 MHz;
- d) either:
 - 1) an arbitrary waveform generator; or
 - 2) two signal generators, with external triggers or gates, capable of producing two gated bursts of sinusoidal radio frequency signals. The amplitudes of the two signals shall be independently variable by up to 20 dB;

If two signal generators are used, suitable matching circuits shall be used to combine the output of the two generators into one test signal;
- e) a protection circuit; an example is shown in [Figure 2](#);
- f) a counter timer capable of generating an overflow pulse after 1 000 trigger pulses and measuring the interval between two pulses with an accuracy of 0,01 %;
- g) an impedance analyser;
- h) environmental test chamber;
- i) a variable power supply suitable to replace any battery used in the ultrasonic instrument;
- j) a variable transformer to control mains voltage.

All the tests in group 1 use electronic means for generating the required signals. The characteristics of the equipment employed and its stability shall be adequate for the purpose of the tests.

The test conditions and the equipment used for the evaluation of the instrument parameters shall be documented.

Before connecting the oscilloscope and/or spectrum analyser to the transmitter of the ultrasonic instrument, as required for some of the tests in this document, it shall be checked that the measuring instruments will not be damaged by the high transmitter voltage.

8.2 Battery operational time

8.2.1 Procedure

The operational time of the unloaded (without any probe connected) ultrasonic instrument using batteries only (i.e. the instrument should be disconnected from the main power supply) shall be measured with the following conditions:

- fully charged new battery(ies);

- ambient temperature between 20 °C and 30 °C;
- gain set to mid-gain position.

If the instrument features a screen:

- display A-scan presentation;
- brightness set at mid-range.

When made possible by the characteristics of the instrument:

- pulse repetition frequency set at least 1 kHz;
- pulse voltage at least 50 V;
- pulse duration at least 100 ns, if applicable;
- time base set to 50 μ s.

In all other cases, those parameters shall be set to their typical values. Parameters that have been modified shall be specified by the manufacturer.

8.2.2 Acceptance criterion

The duration measured shall be higher than or equal to the duration specified by the manufacturer.

8.3 Stability after warm-up time

8.3.1 Procedure

Set the instrument range to 50 mm with a sound velocity of 5 920 m/s and set to full rectification. Ensure that the mains or battery voltage is within the ranges required by the manufacturer's technical specification.

In mid-frequency range of the instrument adjust the signal generator to produce a single cycle sine wave. Add a time delay equivalent to approximately 50 % of the sound path range. Set the amplitude of the signal to be 80 % of the FSH.

Observe the amplitude and the position of the signal on the time base at 10 min intervals over a period of 30 min.

8.3.2 Acceptance criteria

During a 30 min period after warm-up time, in accordance with the manufacturer's technical specification:

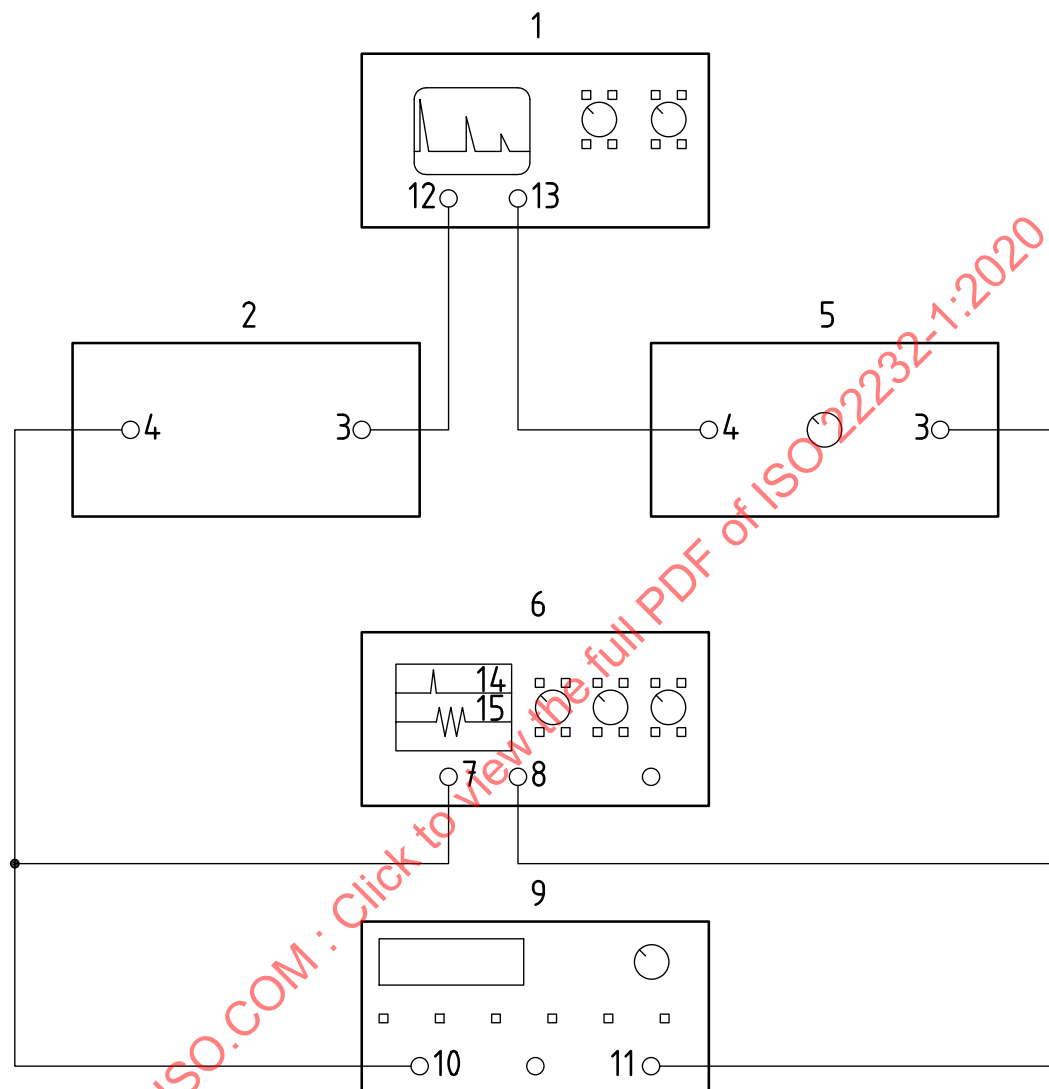
- a) the signal amplitude shall not vary by more than ± 2 % of the FSH;
- b) the maximum acceptable shift along the time base shall be less than ± 1 % of the full screen width (FSW).

8.4 Stability against temperature

8.4.1 Procedure

The ultrasonic instrument is placed into a climatic chamber (relative humidity between 40 % and 60 %) and subjected to varying ambient temperatures. The signal height and position on the instrument screen shall be read off and recorded at a maximum of 10 °C intervals over the temperature range specified by the manufacturer.

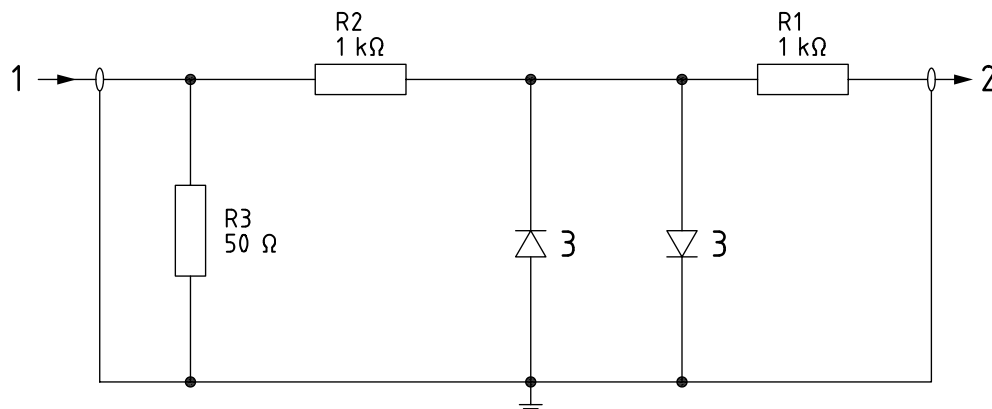
Switch the instrument to separate transmitter-receiver mode. Connect the transmitter output to the first channel of a dual-channel oscilloscope and the trigger input of a signal generator (see [Figure 1](#)). Connect the signal generator gated output to the instrument receiver input and also to the second channel of the oscilloscope.



Key

- | | | | |
|---|--|----|-----------------------------------|
| 1 | ultrasonic instrument | 9 | gated RF signal generator |
| 2 | protection circuit (see Figure 2) | 10 | external trigger input |
| 3 | input | 11 | RF output |
| 4 | output | 12 | transmitter output |
| 5 | variable attenuator | 13 | receiver input |
| 6 | 100 MHz oscilloscope | 14 | voltage limited transmitter pulse |
| 7 | input channel A | 15 | test signal |
| 8 | input channel B | | |

Figure 1 — Setup for measuring stability against temperature

**Key**

- 1 from ultrasonic instrument
 2 to signal generator/oscilloscope
 3 silicon switching diodes
 R1, R2, R3 resistors

Figure 2 — Circuit to protect the instrument from the transmitter pulse

Set the instrument range to 50 mm for a sound velocity of 5 920 m/s, full rectification. Set the oscilloscope channel 1 to view the instrument transmitter pulse. Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz with a delay of 10 μ s. Set the burst amplitude to 1 V peak-to-peak. Adjust oscilloscope channel 2 to view the burst. Now adjust the instrument gain control to set the viewed signal to 80 % of the FSH.

8.4.2 Acceptance criterion

For each 10 °C change in temperature the amplitude of the reference signal shall not change by more than ± 5 % and the position shall not change by more than ± 1 %.

8.5 Stability against voltage variation

8.5.1 Procedure

Instruments which only use line power shall be connected to the variable transformer to control the power voltage. Instruments which use a battery as a primary source of power shall be powered from a regulated power supply in place of the battery.

Tests of variation of the following shall be performed:

- line power over the manufacturers recommended range; and
- variation of battery voltage over the range of voltages which the battery will supply during a full charge and discharge cycle.

In the case of an instrument which can be powered and operated whilst the battery is charging, the test for variation of line voltage to the charger shall also be performed.

If an automatic cut-off system or warning device is fitted, decrease the mains and/or battery voltage and note the signal amplitude at which the cut-off system or warning device operates.

Switch the instrument to separate transmitter-receiver mode. Connect the transmitter output to the first beam of a dual-beam oscilloscope and the trigger input of an RF signal generator (see [Figure 1](#)). Connect the signal generator gated output to the instrument receiver input and also to a second beam of the oscilloscope.

Set the instrument range to 50 mm for a sound velocity of 5 920 m/s, full rectification. Set the oscilloscope beam 1 to view the instrument transmitter pulse. Set the signal generator to generate a burst of three cycles at 2 MHz to 6 MHz with a delay of 10 μ s. Set the burst amplitude to 1 V peak-to-peak. Adjust the oscilloscope beam 2 to view the burst. Now adjust the instrument gain control to set the viewed signal to 80 % of the FSH.

Observe the consistency of amplitude and position on the time base of the reference signal over the ranges defined in the technical specification.

8.5.2 Acceptance criterion

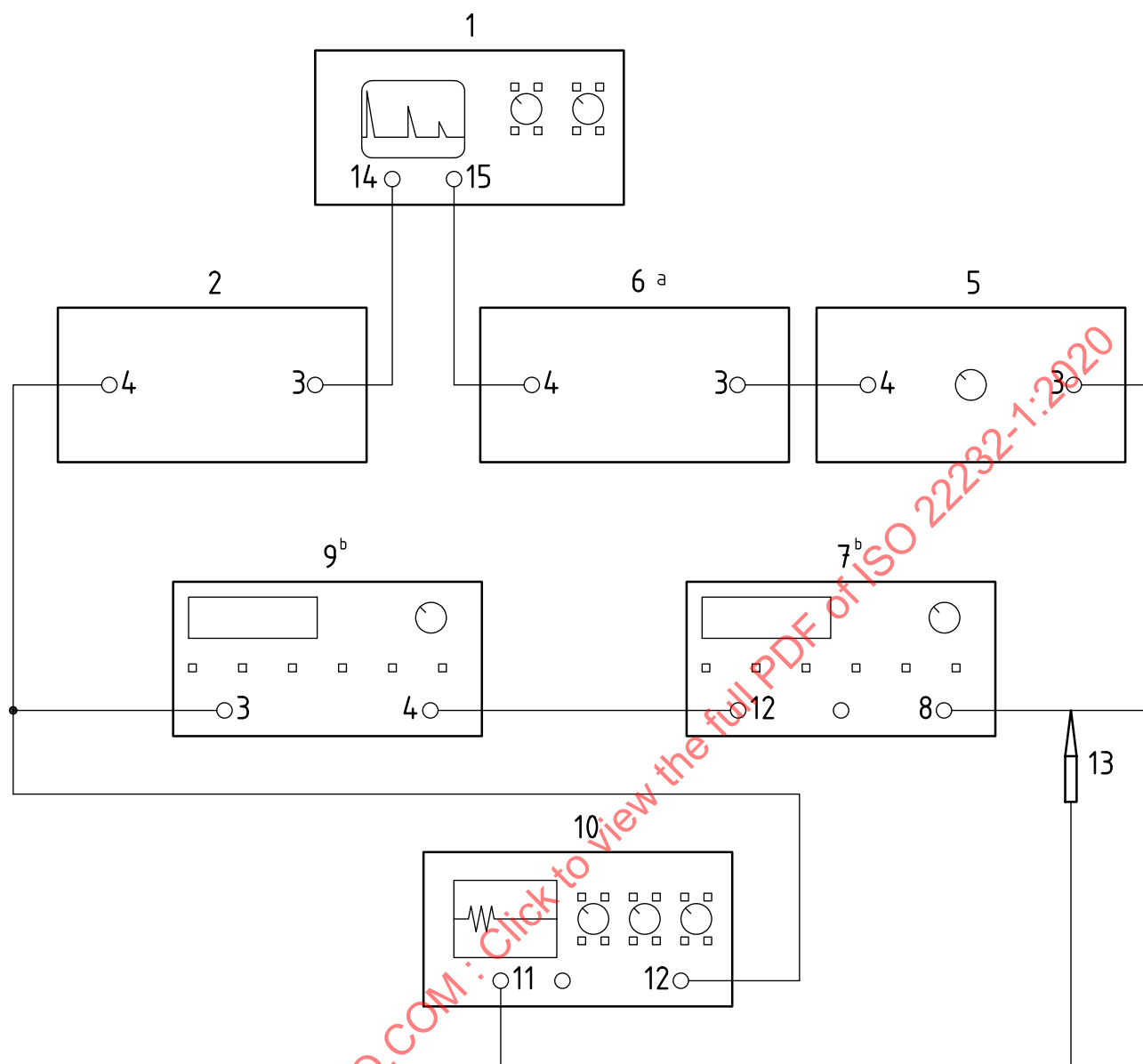
The amplitude of the reference signal shall not change by more than ± 5 % and the position shall not change by more than ± 1 %. Operation of automatic cut-off or warning light (if fitted) shall occur before the reference signal amplitude varies by more than ± 2 % of the FSH or the range changes by more than ± 1 % of the FSW from the initial setting.

8.6 Time base deviation

8.6.1 Procedure

This test compares the time base linearity of the ultrasonic instrument with that of an external calibrated generator.

Connect the instrument as shown in [Figure 3](#). Set the pulse generator to produce a single-cycle sine wave, with a frequency at the centre frequency, f_0 , of the widest frequency range. Set the time base to minimum, maximum and mid-range position in turn. At each setting, adjust the trigger delay, the gain of the ultrasonic instrument, and the external calibrated attenuator to obtain a signal which is at least 80 % of the FSH at the centre of the time base. This step defines the time references of the pulse generator.



Key

- | | | | |
|---|--|----|-----------------------------------|
| 1 | ultrasonic instrument | 9 | pulse generator/counter |
| 2 | protection circuit (see Figure 2) | 10 | 100 MHz oscilloscope |
| 3 | input | 11 | input channel A |
| 4 | output | 12 | external trigger input |
| 5 | variable RF attenuator | 13 | $\times 10$ scope probe (100 MHz) |
| 6 | termination pad | 14 | transmitter output |
| 7 | gated RF signal generator | 15 | receiver input |
| 8 | RF output | | |
- a Termination pad is only required to match the impedance of the ultrasonic instrument to the variable RF attenuator.
- b Gated RF signal generator (7) and pulse generator/counter (9) can be replaced by an arbitrary waveform generator.

Figure 3 — Setup of equipment for multiple tests

Vary the trigger delay of the pulse generator in increments smaller than or equal to 5 % of the screen width.

Record each delay and measure the instant corresponding to the location of the indication (leading edge or maximum amplitude) on the ultrasonic instrument.

For each measurement, calculate the difference between the time read on the ultrasonic instrument and the delay given by the generator.

8.6.2 Acceptance criterion

The maximum deviation shall not exceed either $\pm 0,5$ % of the screen width or the time resolution of the instrument.

8.7 Transmitter pulse parameters

8.7.1 General

This sub-clause contains tests for the pulse repetition frequency and the effective output impedance. Test methods and acceptance criteria for transmitter voltage, rise time and duration are given in [9.3](#).

8.7.2 Pulse repetition frequency

8.7.2.1 Procedure

Switch the ultrasonic instrument to separate transmitter-receiver mode and connect an oscilloscope to the transmitter terminal.

Check that the oscilloscope input will not be damaged by the high transmitter voltage. Connect the oscilloscope to the ultrasonic instrument transmitter terminal using a 100× or 50× probe.

Adjust the oscilloscope to display at least two pulses. The repetition frequency is the reciprocal of the time between the pulses. Because of possible interaction between the pulse repetition frequency (PRF) and the test range control, verify that the PRF is not limited by the test range. To be sure of measuring the true PRF, signal processing functions, e. g. TCG or distance-amplitude compensation, shall be disabled.

Measure the pulse repetition frequency, using the oscilloscope, at minimum, maximum and a typical setting for the pulse repetition frequency.

8.7.2.2 Acceptance criterion

At each setting, the measured value of the pulse repetition frequency shall be within ± 5 % of the selected value or of that stated in the technical specification.

8.7.3 Effective output impedance

8.7.3.1 Procedure

Using the methods in [9.3.1](#), measure the transmitter pulse voltage V_{50} with the transmitter terminated by a 50 Ω non-reactive resistor. Replace the 50 Ω resistor with a 75 Ω resistor and measure, using the oscilloscope, the transmitter pulse voltage V_{75} with the transmitter terminated by a 75 Ω resistor. The measurement shall be made for maximum and typical pulse energy setting and maximum and typical pulse frequency, at maximum and minimum pulse repetition frequencies, with both maximum and minimum damping.

For each setting calculate the effective output impedance Z_o by means of [Formula \(1\)](#):

$$Z_o = 50 \times 75 \frac{(V_{75} - V_{50})}{(75V_{50} - 50V_{75})} \Omega \quad (1)$$

NOTE Voltages V_{50} and V_{75} are the values of the maximum excursions of the respective pulses from the baseline.

8.7.3.2 Acceptance criterion

The effective output impedance shall be within $\pm 5 \Omega$ of the value stated in the technical specification and not greater than 50Ω .

8.8 Receiver

8.8.1 General

This sub-clause gives tests to measure the transmitter-receiver cross talk, the receiver sensitivity, the dead time due to transmitter pulse, the dynamic range, the input impedance, the distance-amplitude correction and the temporal resolution. The methods and acceptance criteria for amplifier bandwidth, equivalent input noise, accuracy of calibrated attenuator, vertical display linearity are given in [9.4](#).

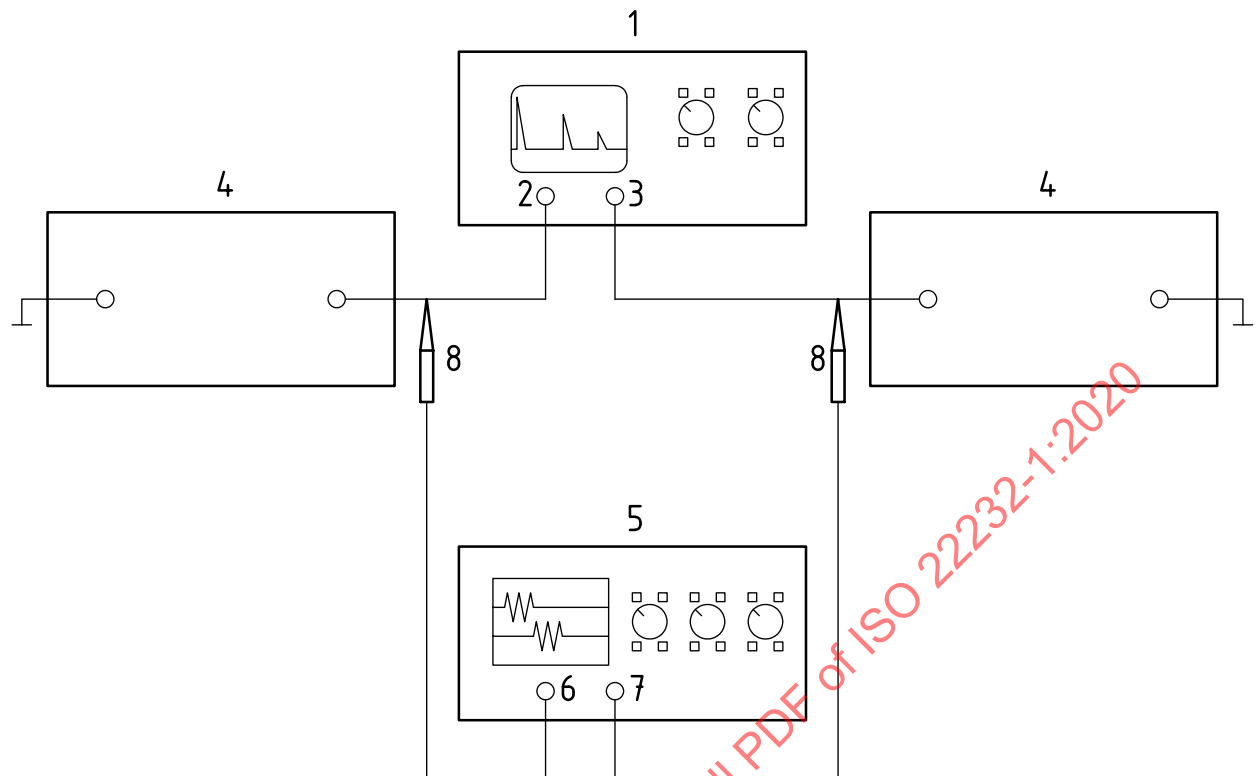
8.8.2 Cross talk from transmitter to receiver during transmission

8.8.2.1 Procedure

Pulser and receiver shall be terminated with 50Ω and the equipment set to separate transmitter-receiver mode.

Measure the peak-to-peak voltages at the pulser output V_{50} and the receiver input V_E with an oscilloscope as shown in [Figure 4](#). The logarithm of the ratio of both voltages is specified as the cross talk during transmission D_s , given in decibels (dB), see [Formula \(2\)](#).

$$D_s = 20 \log_{10} \left(\frac{V_{50}}{V_E} \right) \quad (2)$$

**Key**

- | | | | |
|---|-----------------------|---|----------------------|
| 1 | ultrasonic instrument | 5 | 100 MHz oscilloscope |
| 2 | transmitter output | 6 | input channel A |
| 3 | receiver input | 7 | input channel B |
| 4 | termination pad | 8 | oscilloscope probes |

Figure 4 — Equipment setup used to measure cross talk

To prevent additional cross talk from the measurement setup perform separate measurements for transmitter and receiver with the use of only one channel of the oscilloscope.

8.8.2.2 Acceptance criterion

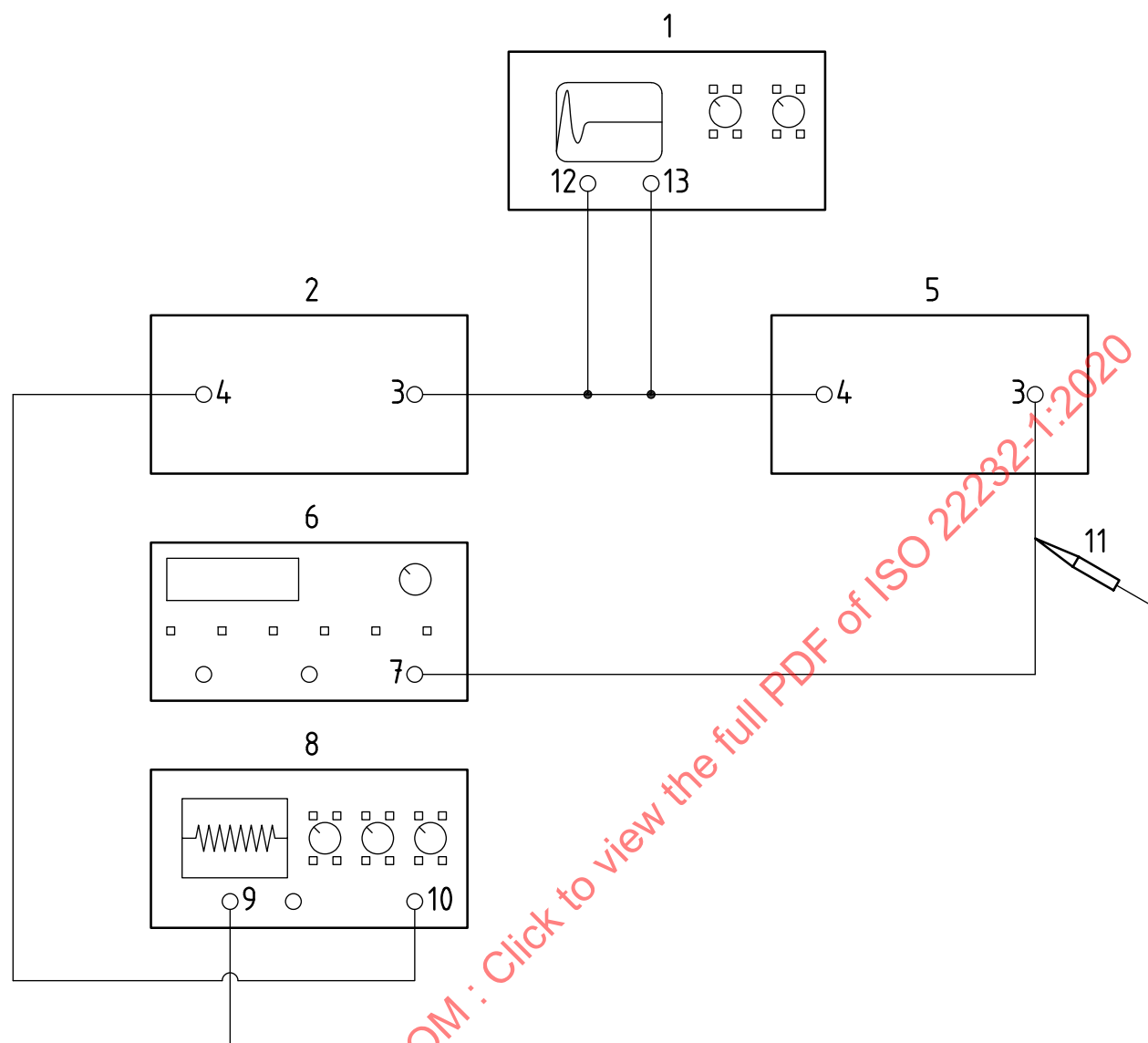
The value of cross talk during transmission (D_s) shall be higher than 80 dB.

For multi-channel systems the value of cross talk during transmission (D_s) shall be higher than the value stated in the manufacturer's technical specification.

8.8.3 Dead time after transmitter pulse**8.8.3.1 Procedure**

Set the ultrasonic instrument screen width from 0 μ s to 25 μ s at full scale. Then adjust the zero offset so that the leading edge of the transmitter pulse coincides with the zero screen division.

Use the equipment setup as shown in [Figure 5](#) with the ultrasonic instrument in single-transducer mode (connected transmitter and receiver).

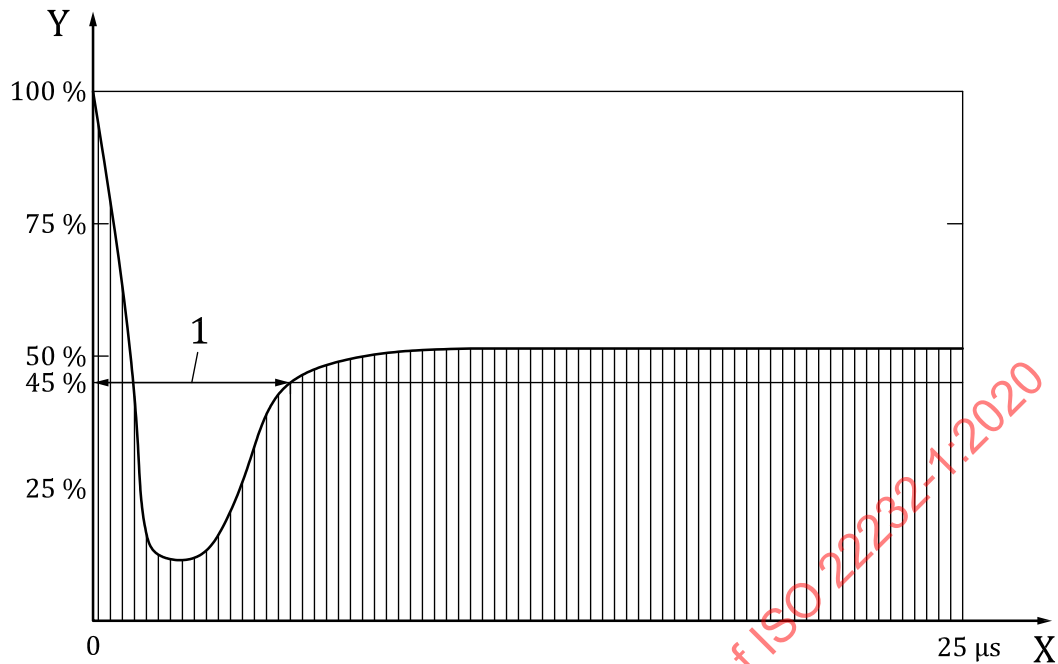


Key

- | | | | |
|---|--|----|---------------------------|
| 1 | ultrasonic instrument | 8 | 100 MHz oscilloscope |
| 2 | protection circuit (see Figure 2) | 9 | input channel A |
| 3 | input | 10 | trigger input |
| 4 | output | 11 | ×10 scope probe (100 MHz) |
| 5 | fixed attenuator | 12 | transmitter output |
| 6 | pulse generator | 13 | receiver input |
| 7 | RF output | | |

Figure 5 — Equipment setup used to measure dead time after the transmitter pulse

Select each frequency band setting of the ultrasonic instrument in turn and adjust the signal generator output to be mid-band of the frequency band setting. Using mid-gain setting of the instrument, adjust the signal generator output level to make the signal 50 % of the FSH at the maximum range of the screen, as shown in [Figure 6](#).



Key

- 1 dead time
- X time
- Y screen height

Figure 6 — Waveform used to measure dead time after the transmitter pulse as seen on the instrument screen during the test

Set the transmitter voltage to 50 % of the maximum value and set the pulse duration corresponding to half of the time cycle of the selected frequency, if applicable.

The dead time after the transmitter pulse t_1 is the duration from the leading edge of the transmitter pulse until the amplitude stabilizes between 45 % and 55 % of the FSH. Values for pulse duration and pulse voltage used for measurement have to be recorded.

NOTE The protection circuit shown in [Figure 2](#) is used to protect the external trigger input of the oscilloscope. The fixed attenuator is used to protect the signal generator from the transmitter pulse.

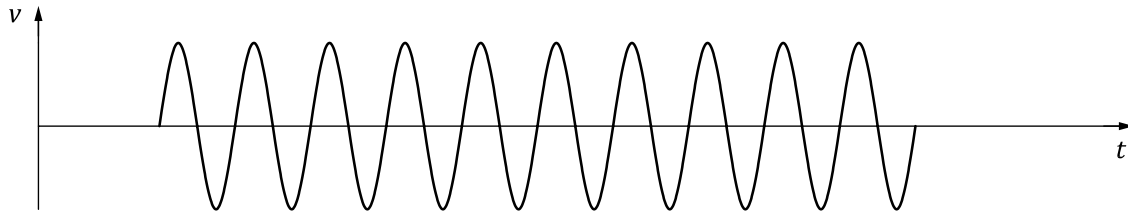
8.8.3.2 Acceptance criterion

The instrument dead time after transmitter pulse shall be less than or equal to the value stated in the manufacturer's technical specification.

8.8.4 Dynamic range and maximum input voltage

8.8.4.1 Procedure

The dynamic range shall be determined using the test equipment in [Figure 3](#) at the centre frequency f_0 of each frequency band as measured in [9.4.2](#). The test signal of ten cycles that shall be generated by this equipment is shown in [Figure 7](#).



Key

v voltage

t time

Figure 7 — Test waveform generated by general purpose equipment setup

Set the ultrasonic instrument attenuator/gain controls (calibrated and uncalibrated) to minimum gain.

Increase the amplitude of the input signal until the signal is displayed at 100 % of the FSH or there is no discernible linear change in signal amplitude for an increase in input signal.

Measure the maximum input voltage amplitude $V_{\max}$, taking due account of the standard attenuator setting.

Set the ultrasonic instrument gain controls (calibrated and uncalibrated) to maximum gain.

If the noise level at the gain setting is higher than 5 % of the FSH, decrease the gain until the noise level is 5 % of the FSH.

Adjust the amplitude of the input signal so that it is displayed at 10 % of the FSH. Measure (taking due account of the standard attenuator setting) the input voltage amplitude $V_{\min}$.

The usable dynamic range, G_D , is given by [Formula \(3\)](#):

$$G_D = 20 \log_{10} \left(\frac{V_{\max}}{V_{\min}} \right) \quad (3)$$

except where $V_{\min}$ is less than the input equivalent noise V_{ein} then the usable dynamic range is limited to:

$$G_D = 20 \log_{10} \left(\frac{V_{\max}}{V_{\text{ein}}} \right) \quad (4)$$

8.8.4.2 Acceptance criteria

The following criteria shall be met:

- the usable dynamic range G_D is dependent of $V_{\max}$ and shall be at least $100 \text{ dB} - 20 \log_{10} \left(\frac{40V}{V_{\max}} \right) \text{ dB}$ in at least one specified frequency range; and
- the minimum input voltage $V_{\min}$ shall be lower or equal than the value stated in the manufacturer's technical specification.

8.8.5 Receiver input impedance

8.8.5.1 Procedure

Real and imaginary parts of the receiver input impedance shall be determined with an impedance analyser with the ultrasonic instrument set for both separate transmitter-receiver mode (dual-transducer mode) and combined transmitter-receiver mode (single-transducer mode). The transmitter

pulse should be disabled while measuring the input impedance in single-transducer mode without disconnecting the receiver from the transmitter. These measurements are to be carried out at a signal frequency of 4 MHz, at the minimum ($R_{\min}$, $C_{\min}$) and maximum ($R_{\max}$, $C_{\max}$) gain setting. A damping control, if fitted, should be set to minimum during the test.

In general, the input impedance can be sufficiently established by an input resistance and a parallel capacitance.

8.8.5.2 Acceptance criterion

At 4 MHz the real part of impedance $R_{\max}$ at maximum gain shall be greater than or equal to 45 Ω and less than or equal to 1 k Ω . The parallel capacity $C_{\max}$ shall be less than or equal to 200 pF. The real components of the input impedance at maximum gain $R_{\max}$ and at minimum gain $R_{\min}$ shall meet [Formula \(5\)](#):

$$\frac{|R_{\max} - R_{\min}|}{R_{\max}} \leq 0,1 \quad (5)$$

The capacitive components of the input impedance at minimum gain $C_{\min}$ and at maximum gain $C_{\max}$ shall meet [Formula \(6\)](#):

$$\frac{|C_{\max} - C_{\min}|}{C_{\max}} \leq 0,15 \quad (6)$$

8.8.6 Time-corrected gain (TCG)

8.8.6.1 Procedure

The performance of the time corrected gain (TCG) shall be verified by comparing the theoretical DAC (distance-amplitude curve) requested by the operator with the actual curve generated by the ultrasonic instrument. The theoretical curve shall be calculated from the information supplied by the manufacturer on the operation of the TCG controls. This shall be compared with the actual curve, which is measured by the change in the amplitude of a test pulse, at a number of N positions on the horizontal time base over which the TCG is active. The DAC selected for this test shall contain the steepest correction slope possible with the ultrasonic instrument.

With the ultrasonic instrument set for separate transmitter-receiver mode with broadest frequency band setting, connect the test equipment as shown in [Figure 3](#). Adjust the gain of the ultrasonic instrument to maximise the dynamic range of the TCG. Throughout this test, avoid saturating the pre-amplifier preceding the TCG circuit.

Enable the TCG selected for the test. With the test signal at a position on the horizontal time base just before the start of the TCG range, adjust the external calibrated attenuator so that the amplitude of the test signal is 80 % of the FSH. Call the standard attenuator setting A_n .

Increase the delay of the test signal to move the test signal along the time base by ΔT where:

$$\Delta T = \frac{T_{\text{final}} - T_0}{N} \quad (7)$$

where

T_0 is the time to the start of the DAC;

T_{final} is the time to the end of the DAC;

N is the number of measurements to be taken; N shall be greater than or equal to eleven.

Adjust the calibrated attenuator to bring the test signal to 80 % of the FSH and record the attenuator setting A_n . Increase the range of the test signal by increasing the time delay by a further ΔT and again record the attenuator setting to bring the test signal to 80 % of the FSH. Continue increasing the time delay and adjusting the standard attenuator until N measurements have been made.

After the last measurement, test the TCG for saturation by increasing the external calibrated attenuation by 6 dB and ensuring that the signal then is between 38 % and 42 % of the FSH. If the signal is not within these limits reduce the range by ΔT and repeat the saturation test. The dynamic range of the TCG shall be measured at the point where saturation no longer occurs.

Plot out the actual DAC and the theoretical DAC.

Repeat the measurement for maximum, medium and minimum TCG gain settings.

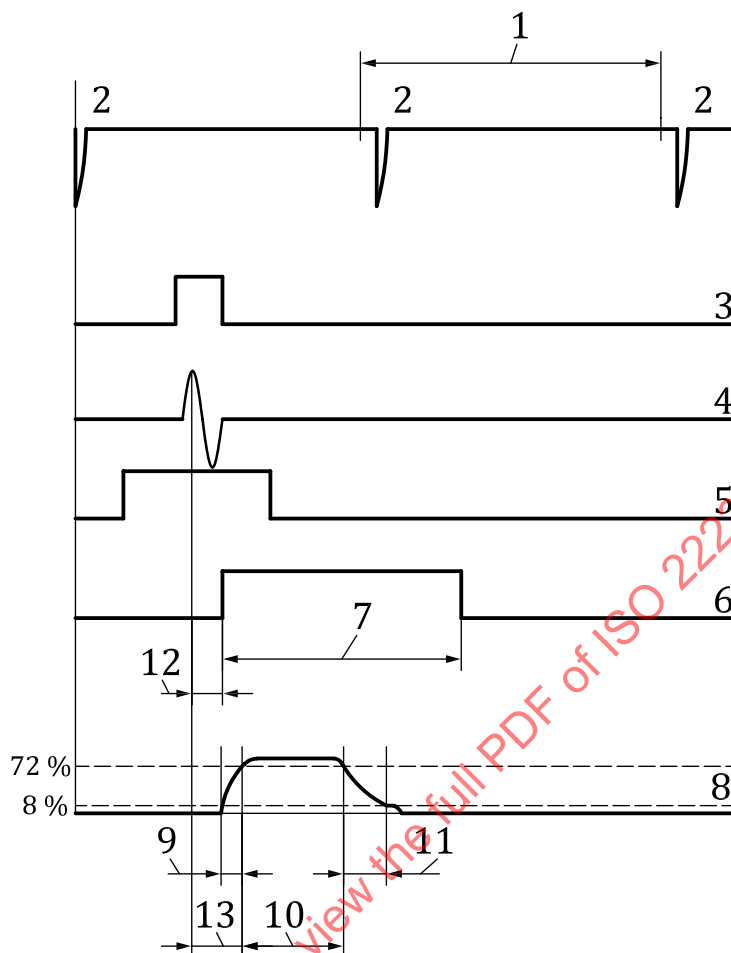
8.8.6.2 Acceptance criterion

The difference between the theoretical DAC (distance-amplitude curve) requested by the operator and the actual DAC shall not exceed $\pm 1,5$ dB.

8.9 Gates

8.9.1 General

For all the gate tests use the equipment setup shown in [Figure 3](#). For all measurements set the ultrasonic instrument to separate transmitter-receiver mode. The generator enables this setup to generate a test signal, as shown in [Figure 8](#). Position the test signals within the gate.



Key

- | | |
|--|-------------------------------|
| 1 screen width | 8 proportional gate output |
| 2 transmitter pulses | 9 rise time |
| 3 test enabling signal | 10 hold time |
| 4 test signal | 11 fall time |
| 5 monitor gate | 12 digital output delay time |
| 6 switched monitor gate signal | 13 analogue output delay time |
| 7 switched monitor gate signal hold time | |

Figure 8 — Timing diagram of signals used to test a monitor gate

8.9.2 Gates with value output

8.9.2.1 Linearity of the amplitude in the gate

8.9.2.1.1 Procedure

Using the setup shown in [Figure 3](#), generate a test pulse synchronised to the transmitter pulse. Select the setting with the gain control at mid-gain and the widest frequency band setting of the ultrasonic instrument.

Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

Adjust the amplitude of the test signal to get an indication at 80 % of the FSH from the gate of the instrument, calling this the reference amplitude.

Change the amplitude of the test signal in steps according to the relative attenuation in [Table 3](#).

The measurement amplitude value in the gate shall be recorded.

Table 3 — Expected gate amplitude for specified attenuator settings

Relative attenuation dB	Nominal value % of the FSH or the maximum possible amplitude value
+1	90
0	80
-2	64
-4	50
-6	40
-8	32
-10	25
-12	20
-14	16
-16	13
-18	10

For equipment capable of measuring signal amplitudes with a gate above 100 % of the FSH, e.g. displayed as value, the vertical linearity shall be tested up to the maximum possible amplitude value.

Adjust the gain to set the signal to 80 % of the maximum gate amplitude value as a reference value. Decrease the gain according to [Table 3](#) and record the signal amplitude values.

8.9.2.1.2 Acceptance criterion

The measurement results shall be equal to the nominal values in [Table 3](#), within ± 2 % of the FSH. For instruments capable of measuring signal amplitudes with a gate above 100 % of the FSH all results shall be equal to the values in [Table 3](#) within ± 2 % of the maximum possible amplitude value.

8.9.2.2 Linearity of time of flight in the gate

8.9.2.2.1 Procedure

The equipment setup shown in [Figure 3](#) is used to generate a test signal for each transmitter pulse. Select a mid-gain position and the widest frequency band setting of the ultrasonic instrument. Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

Adjust the amplitude of the signal with the centre frequency, f_0 , so as to obtain an indication at 80 % of the FSH. Adjust the time base from 0 μ s to 40 μ s. Adjust the monitor gate from 5 μ s to 35 μ s and the height at 50 % of the FSH.

Position the test signal in the first fifth of the screen width, read the value of the time of flight (TOF) from the gate of the instrument and take this as the reference value.

Change the TOF of the test signal is changed in steps according to the delay in [Table 4](#) using the external generator.

The measured TOF value in the gate shall be recorded.

Table 4 — Expected gate TOF for specified positions in the screen width

Position in the screen width %	Nominal time-of-flight value μs
20	Reference
40	Reference + 8 μs
60	Reference + 16 μs
80	Reference + 24 μs

8.9.2.2.2 Acceptance criterion

The measurement results shall be within ±40 ns of the values given in [Table 4](#).

8.9.3 Gates with analogue output**8.9.3.1 Impedance of analogue output****8.9.3.1.1 Procedure**

Select the setting with the gain control at mid-gain and the widest frequency band setting of the ultrasonic instrument.

Adjust the trigger of the measurement signal so that a measurement signal with the carrier frequency, f_0 , as measured in [9.4.2](#), is produced with every transmitter pulse.

Set the amplitude of the measurement signal to produce an indication at 80 % of the FSH and measure the output voltage, V_o . Terminate the analogue output with a resistor of value, R_l , which satisfies [Formula \(8\)](#):

$$0,75I_{\max} \leq \left(\frac{V_o}{R_l} \right) \leq 0,85I_{\max} \quad (8)$$

where $I_{\max}$ is the maximum current that can be driven by the analogue output.

Record the altered output voltage, V_l . The resistive part of the output impedance is calculated using [Formula \(9\)](#):

$$|Z_A| = \left(\frac{V_o}{V_l} - 1 \right) R_l \quad (9)$$

8.9.3.1.2 Acceptance criterion

The measured output impedance shall be within the tolerance stated in the manufacturer's technical specification.

8.9.3.2 Linearity of analogue output**8.9.3.2.1 Procedure**

Select the setting with the gain control at mid-gain and the widest frequency band setting of the ultrasonic instrument.

Adjust the triggering of the test signal so as to produce a signal for each transmitter pulse.

Adjust the amplitude of the test signal to give an indication at 80 % of the FSH and measure the voltage at the analogue output, calling this the reference voltage. The output voltage corresponding to an indication at full screen height is equal to 1,25 times the reference voltage with a tolerance of +2 dB.

Change the amplitude of the test signal in steps according to [Table 5](#).

The measured output voltage value shall be recorded.

Table 5 — Expected output voltage for specified attenuator settings

Relative attenuation dB	Nominal value % of the reference voltage
+1	90
0	80
-2	64
-4	50
-6	40
-8	32
-10	25
-12	20
-14	16
-16	13
-18	10

For equipment capable of measuring signal amplitudes above 100 % of the FSH, the linearity of the analogue output shall be checked up to the maximum possible amplitude value.

Adjust the gain to set the signal to 80 % of the maximum possible gate amplitude value of the analogue output voltage as a reference value.

Decrease the gain according to [Table 5](#) and record the voltage of the analogue output.

8.9.3.2.2 Acceptance criterion

All measurement result shall be within the tolerance stated in the manufacturer's technical specification.

8.9.3.3 Influence of the signal position within the gate

8.9.3.3.1 Procedure

Use the equipment setup shown in [Figure 3](#) to generate a test signal for each transmitter pulse. Select a mid-gain position and the widest frequency band setting of the ultrasonic instrument. Adjust the amplitude of the signal with the centre frequency, f_0 , so as to obtain an indication at 80 % of the FSH. Position the test signal in the first fifth, in the centre, then in the last fifth of the gate and measure the voltages of the analogue output.

8.9.3.3.2 Acceptance criterion

All measurement results shall be within the tolerance stated in the manufacturer's technical specification.

8.9.3.4 Rise time, fall time, delay time and hold time of analogue output

8.9.3.4.1 Procedure

Use the equipment setup shown in [Figure 3](#) to set the triggering of the test signal so as to produce a signal for each transmitter pulse. Select a mid-gain position and the widest frequency band setting of the ultrasonic instrument and a test signal with the carrier frequency, f_0 , measured in [9.4.2](#).

Adjust the test signal so as to produce a voltage at the analogue output equal to 80 % of the output voltage for the FSH. Change the trigger of the test signal so that at the analogue output, the minimum output voltage can be observed between two consecutive pulses (e.g. a transmitter pulse producing a test signal is followed by approximately one thousand pulses for which no signal is produced).

The rise time, fall time, delay time and hold time shall be measured as follows and recorded:

- a) the rise time is the time interval during which the output voltage increases from 8 % to 72 % (see [Figure 8](#)); these values are equivalent to 10 % and 90 % of the output signal produced by the test signal;
- b) the fall time is the time interval during which the output voltage decreases from 72 % to 8 % (see [Figure 8](#)).
- c) the delay time is the time interval from the peak of the test signal till the output voltage is above 72 % (see [Figure 8](#));
- d) the hold time is the time interval during which the output voltage is above 72 % (see [Figure 8](#)).

8.9.3.4.2 Acceptance criterion

All measurement results shall be within the tolerance stated in the manufacturer's technical specification.

8.9.4 Gates with alarm output

8.9.4.1 General

This sub-clause describes tests for any monitor gates with binary switching output, also known as alarm output or go-no go output.

The monitor output shall be wired according to the manufacturer's technical specification and a diagram of this circuit shall be made.

All the monitor gate tests shall use the equipment setup shown in [Figure 3](#). In this setup, the trigger for the test signal is derived from a transmitter pulse using a protection circuit, a counter timer and a pulse generator. As shown in [Figure 3](#) the counter timer enables this setup to generate a test signal for one transmitter pulse followed by a large number (at least 1 000) of transmitter pulses for which no test signal is generated.

8.9.4.2 Response threshold and switching hysteresis

8.9.4.2.1 Procedure

Adjust the sound path range to 100 mm at a sound velocity of 5 920 m/s. For all frequency bands on the instrument adjust the signal generator to produce a single-cycle sine wave at the centre frequency, f_0 . Add a time delay equivalent to approximately 50 % of the sound path range. Turn on a gate and adjust its length to be from 40 % to 60 % of the sound path range. Set the gate threshold to be 40 % of the FSH if the gate threshold is adjustable.

Adjust the amplitude of the test signal until the gate alarm turns on. Note this amplitude, $A_{G,on}$. Adjust the test signal amplitude until the gate alarm turns off. Note this amplitude, $A_{G,off}$, too. The difference in the amplitudes to turn the gate alarm on and off is the switching hysteresis and its mean value is the gate threshold.

8.9.4.2.2 Acceptance criteria

For gates with thresholds the amplitudes that turn the gate alarm on and off shall be within the tolerances stated in the manufacturer's technical specification.

8.9.4.3 Delay time and hold time of the gate alarm

8.9.4.3.1 Procedure

Set the amplitude of the trigger signal so that the gate alarm is on. Then change the trigger of the measurement signal so that a transmission pulse with trigger signal is followed by approximately one thousand pulses without a trigger signal, as shown in [Figure 8](#).

Measure the time interval between the maximum peak of the test signal and the time the gate alarm turns on, at its 50 % level. This is the delay time.

Measure the time interval between the time the gate alarm turns on and the time when the gate alarm turns off, at its 50 % level. This is the hold time. If outputs are available with different hold times, measurements shall be carried out for all outputs.

8.9.4.3.2 Acceptance criteria

The delay time and the hold time of the alarm output shall be within the tolerances stated in the manufacturer's technical specification.

8.10 Highest digitized frequency

8.10.1 Procedure

8.10.1.1 General

This test shall verify that a signal, having the highest frequency within the ultrasonic instrument bandwidth, is correctly displayed on the screen, and particularly that its amplitude is independent of its sound path range.

The test should be done with the broadest frequency band setting in rectified and RF mode, if available, and with TCG disabled. The test should also be repeated with each setting of the sampling frequency.

Carry out the measurements for digitisation sampling error using one of the following methods given in [8.10.1.2](#) and [8.10.1.3](#). The used method shall be reported.

8.10.1.2 Method A

Set the ultrasonic instrument for separate transmitter-receiver mode and, using the setup shown in [Figure 3](#), to generate a test pulse synchronised to the transmitter pulse. Set the delay T of the signal to T_0 , longer than the receiver dead time. Set the frequency of the signal generator to f_u , as determined in [9.4.2](#), using the broadest frequency bandwidth setting. Adjust the signal generator to produce a single-period sinusoid with an amplitude of 80 % of the FSH.

Using the variable time delay, increase T by a small increment according to [Formula \(10\)](#):

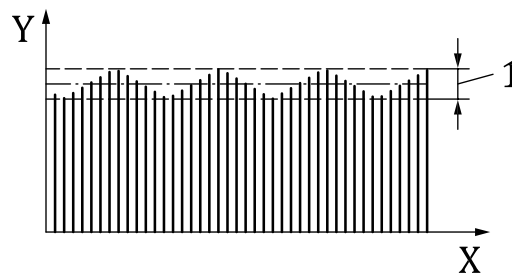
$$\Delta T = \frac{1}{10 f_u} \quad (10)$$

At each increment of ΔT , measure the amplitude of the signal on the screen. Continue increasing the time delay and measuring the amplitude until 30 measurements have been made (i.e. three wavelengths).

8.10.1.3 Method B

Set the ultrasonic instrument for separate transmitter-receiver mode using the setup shown in [Figure 3](#). Calibrate the ultrasonic instrument screen width from 0 μ s to 25 μ s at full scale. Then adjust the zero offset so that the zero screen division starts well after the dead time as determined in [8.8.3](#). Set the frequency of the signal generator to f_u , as determined in [9.4.2](#), for the selected filter setting of the

instrument. Adjust the signal generator to produce a continuous sine wave with an average amplitude of 80 % of the FSH. Record the minimum and maximum signal amplitudes displayed on the screen of the instrument as shown in [Figure 9](#).



Key

- X time
- Y screen height
- 1 digitisation sampling error

Figure 9 — Waveform used with method B to measure the digitisation sampling error

For this measurement it is important that the frequency generated by the signal generator is not synchronous to the sampling clock of the instrument. This can be verified by setting the frequency of the signal generator to a frequency of $f_u - 0,1$ MHz. Again observe the minimum and maximum signal amplitudes displayed on the screen of the instrument. The observed values should not change due to this small frequency variation. Record the lowest minimum amplitude and the largest maximum amplitude and the signal frequency used.

8.10.2 Acceptance criterion

The signal amplitudes shall stay within 75 % and 85 % of the FSH.

8.11 Response time of digital ultrasonic instruments

8.11.1 General

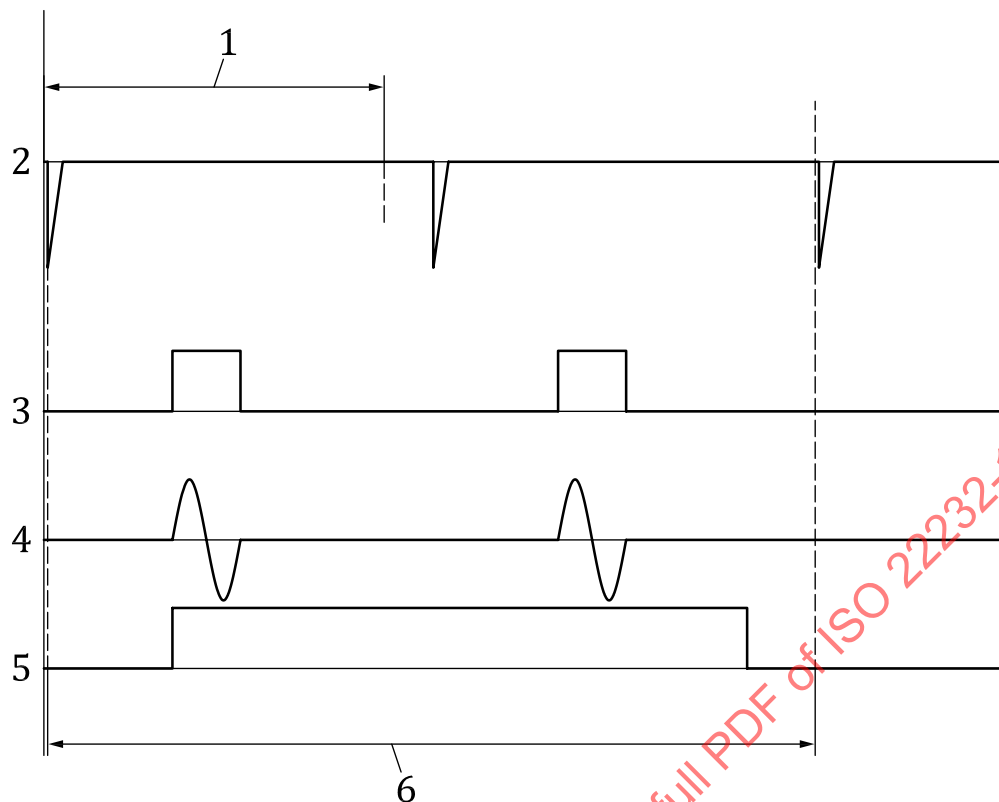
The displays have a limited refresh rate, and this may not match the ultrasonic pulse repetition frequency. Hence transient echoes which are only detected for a short period of time may not be displayed on the screen at their full amplitude. The purpose of this test is to measure the time for which a transient echo has to be detected before it is displayed on the screen of the digital ultrasonic instrument, at 90 % of its full amplitude.

8.11.2 Procedure

Use the same setup as the previous tests ([8.10.1.2](#)) to produce a single-cycle sinusoidal test pulse with a frequency at f_u for the filter as measured in [9.4.2](#). Adjust the ultrasonic instrument gain to the middle of its dynamic range and the amplitude of the test pulse to 80 % of the FSH. Set the signal generator to produce a single-shot pulse, after which the signal generator will require rearming before the next pulse is generated. After arming the test signal, an indication should appear on the ultrasonic instrument screen at 80 % of the FSH.

If no echo appears or the amplitude is not between 75 % and 85 % of the FSH, set the function generator to multi-shot mode and increase the number of shots, by increasing the width of the gate used to enable the signal generator, until the signal is between 75 % and 85 % of the FSH.

Measure the response time of the ultrasonic instrument by measuring the time from the start of the transmitter pulse triggering the test signal gate to the start of the transmitter pulse following the end of the test signal gate, as shown in [Figure 10](#).



Key

- 1 screen width
- 2 transmitter pulses
- 3 test enabling signals
- 4 test signal
- 5 test signals gate
- 6 response time

Figure 10 — Timing diagram showing how to measure the response time of digital ultrasonic instruments

Repeat this test for each setting which influences the response time of the ultrasonic instrument, such as range or pulse repetition frequency setting.

8.11.3 Acceptance criterion

The measured response time shall be within the tolerance stated in the manufacturer's specification.

9 Group 2 tests

9.1 Equipment required for group 2 tests

The items of equipment essential to assess ultrasonic instruments in accordance with the tests in group 2 of this document are as follows:

- a) an oscilloscope with a minimum bandwidth of 100 MHz;
- b) a resistor 50 Ω , with a tolerance of ± 1 %;

- c) a standard 50 Ω attenuator with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency up to 15 MHz;
- d) two signal generators with an external trigger or gate capable of producing a gated burst of sinusoidal radio frequency signals of variable amplitude in the range suitable for the equipment being tested; or an arbitrary waveform generator, capable of producing gated bursts of sinusoidal signals.

All the tests in this document, except for those of stability, use electronic means for generating the required signals. The characteristics of the equipment employed and its stability shall be adequate for the purpose of the tests.

The test conditions and the equipment used for the evaluation of the instrument parameters shall be documented.

Before connecting the oscilloscope and/or spectrum analyser to the transmitter of the ultrasonic instrument, as required for some of the tests in this document, check that the measuring instruments will not be damaged by the high transmitter voltage.

9.2 Physical state and external aspects

9.2.1 Procedure

Visually inspect the outside of the ultrasonic instrument for physical damage which may influence its current operation or future reliability.

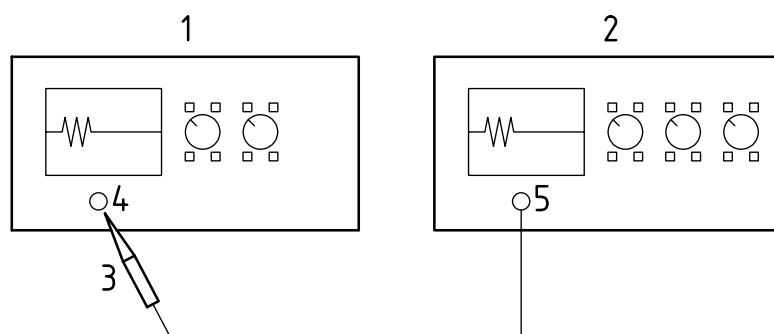
9.2.2 Acceptance criterion

The equipment shall be considered acceptable if no physical damage is noted which may influence the operation or future reliability.

9.3 Transmitter voltage, pulse rise time and duration

9.3.1 Procedure

Start with the setup of [Figure 11](#) with the 50 Ω load connected. Switch the ultrasonic instrument to separate transmitter-receiver mode. Obtain a display on the oscilloscope screen that clearly shows the leading edge of the pulse. Set the pulse repetition frequency to maximum.



Key

- 1 ultrasonic instrument or pulser section
- 2 oscilloscope
- 3 $\times 10$ scope probe
- 4 transmitter output set to impedance of $50\ \Omega$
- 5 input channel A

Figure 11 — Instrumentation for pulse measurements

Using the oscilloscope, measure the transmitter pulse voltage V_{50} , the pulse rise time t_r and the pulse duration t_d as shown in [Figure 12](#).