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Universal High Voltage Reference Divider

Type ID-0500-CD00

Instruction Manual

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1 Safety precautions

1.1 Safety

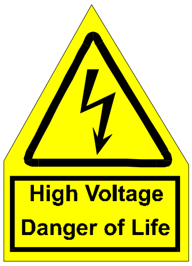
The instrument described in this manual is designed to be used by properly trained personnel only. Adjustment, maintenance and repair of the exposed equipment should be carried out only by qualified personnel aware of the hazards involved.

1.2 Safety precautions

For correct and safe use of this instrument it is essential that both operation and service personnel follow generally accepted safety procedures in addition to the safety precautions specified in the manual. Specific warning and caution statements, where they apply, will be found throughout the manual. Safety is the responsibility of the user.

Warning!

The whole equipment works in high voltage environment and therefore all instructions and precautions which apply for such operations have to be considered working with the measuring instrument.



1.3 Impaired safety precautions

Whenever it is likely that safety protection has been impaired, the instrument must be made inoperative and be secured against any unintended operation. Safety protection is likely to be impaired if, for example, the instrument fails to perform the intended measurements or shows visible damage.

2. Description

2.1 Function Principle

The reference divider is composed of a main divider, a coaxial connection cable and an attenuator (Fig.1.). The reference divider is based on the principle of the well-known “damped capacitor” divider. The theory and practical examples of such dividers have been described in many publications and books.

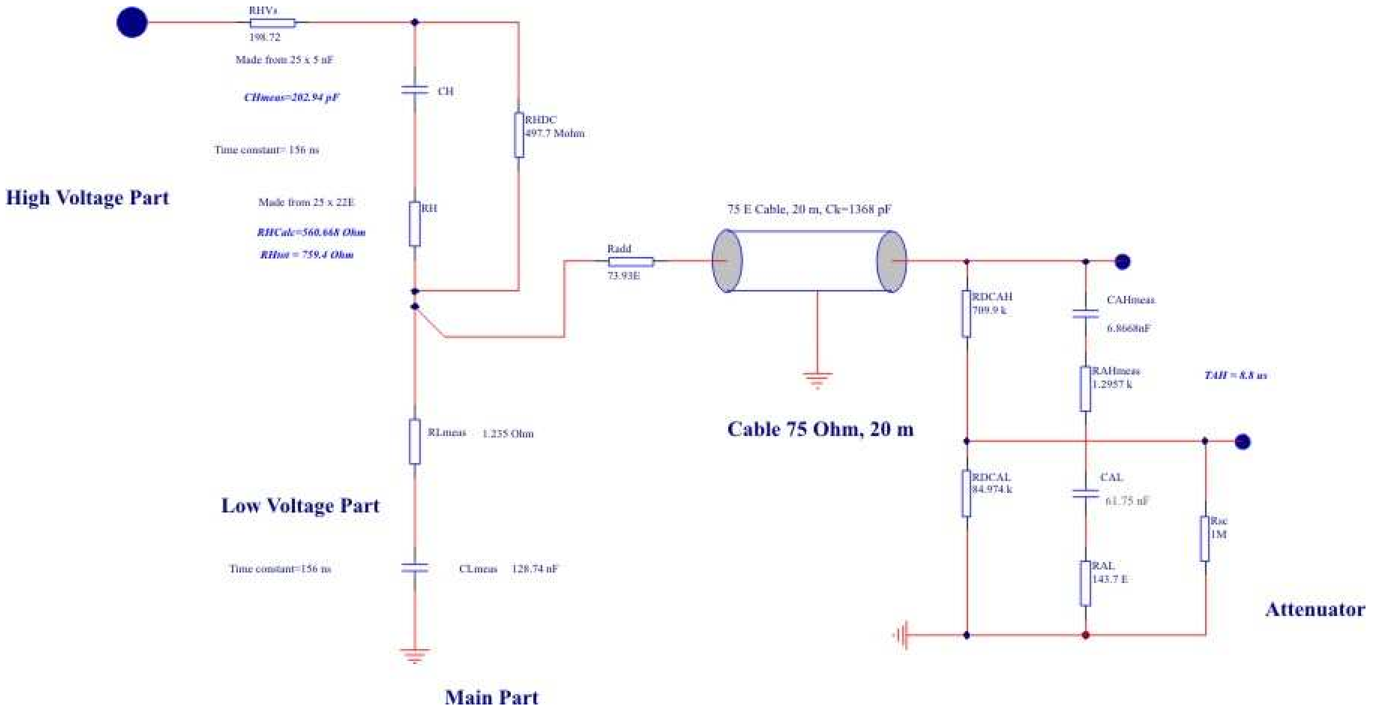


Fig. 1

The main divider consists of a high-voltage (h.v.) arm (series connection of C_H and R_H) and a low-voltage (l.v.) arm (series connection of C_L and R_L). The time constants τ_H and τ_L of each arm are matched for optimum frequency response. The basic working principle can be briefly explained as followed: Consider the divider as a capacitive divider for low frequencies such as mains frequency f=50 Hz (with the resistances R_H and R_L neglected) and as a resistive divider for higher frequencies (reactances of C_H and C_L neglected). In order to provide DC measurement capabilities, an additional resistor branch is connected in parallel to C_H and R_H.(refer to R_{HDC} in the above schematic).The DC branch is made of 40 resistors, each 40 MΩ, 10 W. The l.v. arm of the DC dividing branch is located in the attenuator. Therefore **DC measurements cannot be performed without the attenuator (!)**.

The h.v. arm (series connection of C_H and R_H) is made 25 disk-type low-loss ceramic capacitors (each 5000pF/13 kV) capacitors and 25 pieces impulse-rated 22 Ω resistors. The use of these capacitors and resistors in the divider provides very good long-term stability.

The capacitance C_L of the l.v. arm is formed by capacitors having the same type of dielectrics (Class 1 ceramic) with the same negative temperature coefficient (TC) as the ceramic capacitors that form C_H. Therefore any relative change of the capacitance of C_H due to ambient temperature change is compensated by the same relative change in C_L.

The resistance R_L consists of 9 resistor pairs, each pair being made of two series-connected approx. 5.5 Ω impulse-rated resistors. Thus $R_L \approx (2*5.5\ \Omega) / 9 = 1.2\ \Omega$. This parallel arrangement is necessary to minimize the effect of stray inductance in the l.v. arm. Being a typical phenomenon with impulse high-voltage dividers, excessive inductance would cause severe ringing(oscillations) and distortion of the divided h.v. input signal seen at the output of the divider. Therefore care has been taken in the design of this divider to minimize such effects.

The output of the main divider is matched to the nominal output impedance of Z= 75 Ω by means of the matching resistor R_{add}. A standard coaxial cable, type RG-11/U, Z=75 Ω cable of 20 meters length is used as signal cable and connected to the “C”-type output socket.

The output of the cable is usually connected to the “attenuator”. The attenuator is a additional 10:1-divider that allows for the use of modern digital storage oscilloscopes (DSO), since DSOs do only handle peak voltages of less than approx. 100V. However the reference divider can be used without the attenuator for AC and impulse measurements. This feature is required with most impulse recording systems which handle input voltages up to approx. 1kV. When the main divider is used with the attenuator, the BNC output of the attenuator must be loaded by a 1 MΩ/≈30pF input impedance which is typical with most digital AC voltmeters or oscilloscopes.

The input impedance of the attenuator is not matched to the cable. This can be explained as followed: A voltage step of constant amplitude V over the l.v. arm (R_L and C_L in series) is halved to V/2 at the input of the coaxial cable because of the matching resistor R_{add}. The wave with an amplitude V/2 travels through the cable to the high-impedance load which can be seen as an open end. The voltage at the end of the cable is now doubled by reflection. Hence the original voltage V on the l.v. arm apperars at the high-impedance load (attenuator input or impulse recording system). The reflected wave is finally dissipated in the matching resistor.

The damping resistor consists of nine 22Ω impulse resistors and matches the h.v. input of the main divider to the high voltage circuit. Connection to the impulse generator must be always performed with the damping resistor and the matching aluminum connection rod in order to avoid reflections between the main divider and the source. However the damping resistor can be omitted for DC and AC (mains frequency) applications.

2.2 Design of the measuring system

The High Voltage Part is assembled on a PMMA supporting elements and built into a PMMA tube. The below Fig.2 shows the ceramic disk-type capacitors that form the capacitance C_H, the 22Ω resistors that form R_H and the 40MΩ resistors for the DC-branch R_{HDC}:

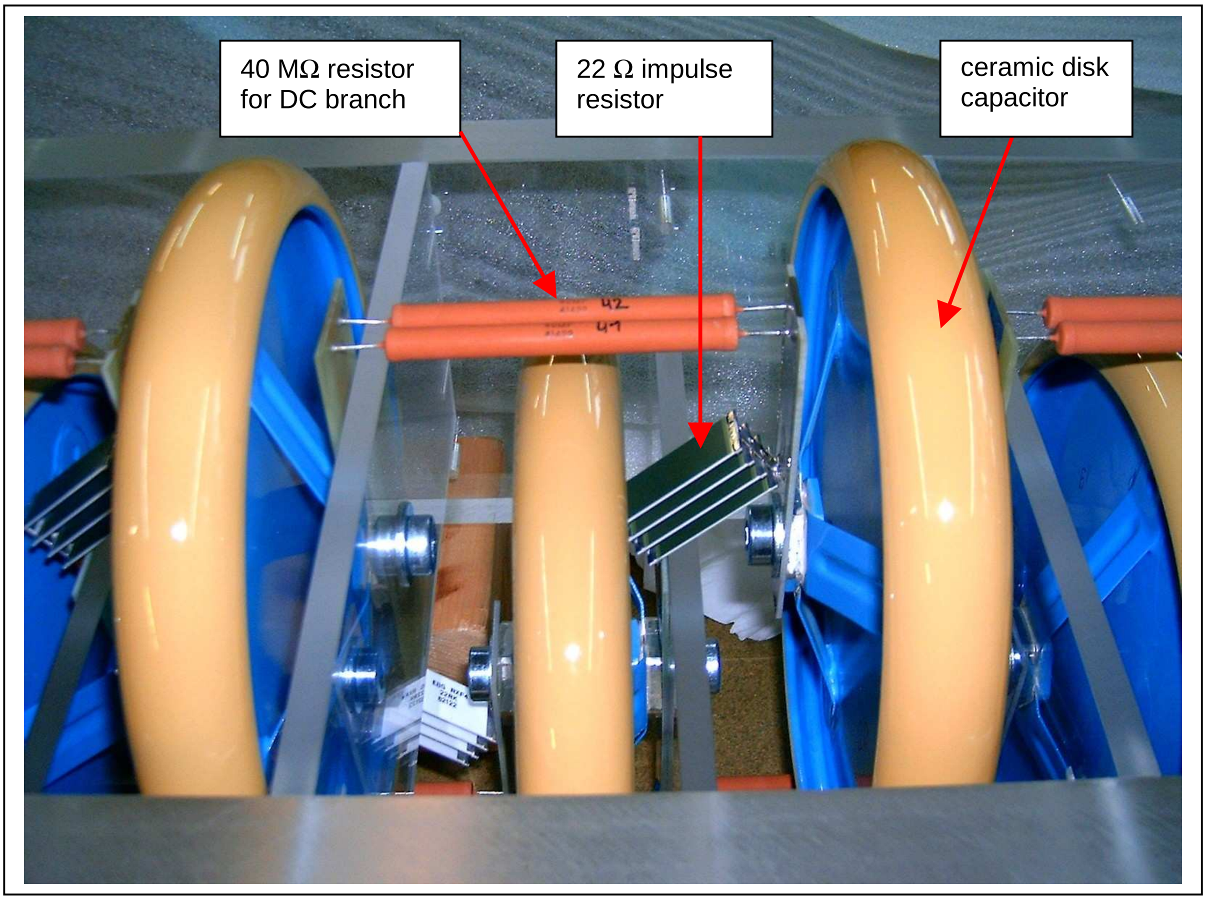


Fig.2.

The l.v. arm is of coaxial construction and is located in the lower part of the divider. The output socket of the main divider is a standard "C" Type HF socket.

The main divider is filled with pure SF_6 gas at low pressure (approx 30 mbar). The gas filling allows for an additional safety margin by avoiding partial discharges within the main divider, especially at DC voltages close to the rated maximum of 250kVDC.

> **NOTE:** The built-in manometer is used by the manufacturer after assembly of the main divider to ensure optimum gas filling. The pressure value indicated by the manometer can show large variations due to temperature change and ambient air pressure (barometric conditions). The variation of gas pressure does not have any influence on the correct operation of the reference divider.

The attenuator is built - in a cylindrical case. The input connector is a type "C" HF coaxial connector. The output is a BNC connector to be used with a short cable to connect to the measuring instrument.

The nine impulse resistors that form the damping resistor are housed in a PMMA tube to prevent damage to the resistors.

2.3. Connection and Operation of the Divider in a High-Voltage Laboratory

In order to assure a safe and reliable operation the main divider must be earthed properly.

Insufficient or inappropriate earth connections can be extremely dangerous due to the possibility of dangerous voltages at the cable connectors and sockets, the attenuator or the attached measuring instrument.

The operator should always be aware of this potential hazard while using the divider !

Furthermore a good earth connection is extremely important in order to avoid the phenomenon of “ground bounce” at the ground terminal of the reference divider. If the inductance of the earth connection is too high, a voltage jump will occur due to the fast current rise in impulse applications (high di/dt values). This voltage can cause parasitic currents in the screen of the coaxial cable and thus distorted waveforms and measurements.

Therefore it is necessary to provide a low-impedance **earth** connection. Inductance and high-frequency resistance are minimized by **using flat copper ribbon of at least 0.5m (approx 20 inches) width and not less than 0.5mm thickness**. A good current return path to the impulse generator or the HV source must be provided in all cases. Copper ribbon provides the lowest impedance for the connection between the generator and the divider.

Independent of the application (DC, AC, lightning impulse or switching impulse) the voltage applied on the reference divider should never exceed the specified ratings ! Exceeding the nominal ratings may cause damage to the main divider or attenuator.

Therefore it is generally advisable to gradually increase the applied voltage from a comparatively low value (e.g. 25% of the nominal rating) to the desired value.

The connection cable should not be close to high-pulse current paths since this might cause interference and distortion of the measurement. Therefore it should be positioned out of the current loop formed by the impulse generator, the test object and/or the reference divider.

Using the reference divider for impulse measurement such as lightning impulse measurement always requires the matching damping resistor together with the aluminium connection rod. The damping resistor unit should be placed at the generators side to correctly damp the high voltage circuit.

The operator should be very cautious when handling the connection rod with the damping resistor mounted in order to prevent damage to the resistor elements by mechanical shock.

A further very important safety measure to **avoid lethal hazards** in high-voltage laboratories is to have the laboratory equipped with a “earthing rod”. The earthing rod should be connected to laboratory earth using a wire of >25 mm^2 cross-section.

The operator must always earth the high-voltage terminal of a generator or source before further manipulations in the laboratory. This is absolutely mandatory with high-voltage DC sources !

3. Technical Data

Universal High Voltage Reference Divider **Type ID-0500-CD00**

Rated voltages

Lightning impulse voltage	500 kV
Front- chopped lightning imp. Voltage	500 kV
AC Voltage	200 kV_{RMS}
DC Voltage	250 kV

Measurement uncertainty

Lightning impulse voltage	± 0.5 %
Front- chopped lightning imp. voltage (Tc=500 ns)	± 2 %
AC Voltage	± 0.5 %
DC Voltage	± 0.5 %
Time parameters	± 2 %

Unit step response data

Experimental response time TN	< 15 ns
Partial response time T_{α}	< 20 ns
Settling time t_s	< 150 ns

Impedances and ratios

High voltage capacitor CH	~ 200 pF
Scale factor without LV attenuator	~ 630
DC HV resistor	~ 500 MΩ
AC scale factor	~ 630
DC scale factor	~ 630
Matching	75 Ω

Reference conditions

Temperature	23°C ± 2°C
Humidity	45 ... 75 %
Barometric pressure	101.3 kPa

Rated range of use

According IEC 359	
Temperature	5°C ... 40°C
Humidity, non condensing	20 ... 95 %
Barometric pressure	70 ... 106 kPa

Miscellaneous

Divider height	2.3 m
Length of HV lead including R_D	3 m
Net weight without connection cable	70 kg

<u>Low voltage attenuator for a scale factor of 6’300</u>

Impedance and ratios

For impulse AC and DC	
Scale factor with the HV attenuator	~ 6’300
Matching	75 Ω

<u>Damping Resistor and HV Connection</u>

Length	3 m
Damping Resistor	approx. 180 Ω
Length of damping resistor	0.8 m

<u>Coaxial Cable, screened</u>

Length	20 m
Matching	75 Ω
Connectors	Type C