30 KV Generator

Peter Göttlicher

DESY-FEB

22-Dec-1999

Abstract

The instrument was designed for the development of a transient recorder, which should survive a transient of 30kV. The 30kV generator charges a capacitor chain up to 30kV. That charge is available for a discharge through a resistor for testing electronics. Because the input impedance of the transient recorder are two parallel resistors of 120kOhm, the discharge resistor inside the 30kV-generator is 60kOhm.

The mechanical design takes into account, that the high voltage is only available inside the box and does not leave the instrument. Also the customer electronics to be tested (One EURO board) fits into the box. That area is separated by plastic walls from the rest of the instrument. In is also accessible without opening the rest of the instrument. While also that area is closed a test point can be reached with a HV-probe from outside.

Specification of the available charge

The charge is stored in a chain of capacitors (see circuit diagram page 1 .) The nominal value of the capacitor is 2.32nF, but it is degrading with increasing voltage. The main capacitor (1nF 15kV, Murata, Type "DHR-20B-102M-15K") have a 25% less capacitance at fully charged chain (30kV over the chain or 10kV at capacitor). Therefore the capacitance of the chain can be Estimated as:

Voltage of CHAIN (kV)	Capacitance (nF)	Available charge (uC)
0.0	2.3	0
5.0	2.3	12
10.0	2.3	23
15.0	2.1	32
20.0	1.9	38
25.0	1.8	45
30.0	1.7	51

Estimated Capacitance of HV chain versus charged voltage.

During the discharge the peak current should be well below 8A, because the last diode (HV side) in the charging chain can deliver only a current I_FWM=4A (Type BY228 or BY448, Philips) . Half of the discharge current is flowing through this diode. At the supply side of the chain diodes are installed which handle only 0.5A (Philips BY8412) but a higher differential voltage. With the 60kOhm discharge resistor - the only tested condition - the peak current is 0.5A .

Setup and Operation

The 30kV Generator is designed as a laboratory instrument and constructed only as a prototype. Therefore generators and measurements available as standard equipment are not integrated into the 30kV-Generator.

The complete setup is shown together with the circuit diagrams: page 5 .)

The following additional instruments are needed:

- Pulse generator (and amplifier) 2--3 kHz, 30--50V peak peak, sine wave, Philips 5131, Toellner TOE7607
- Oscilloscope
- HV-Probe with Multimeter/Scope to see the voltage during discharge might be useful

For the begin of charging the chain turn down the amplitude. Pull the HV switch. While turing up the charging amplitude at the pulse generator/amplifier watch, that the peak to peak amplitude on the scope does not exceed 1.6kV and the total amplitude should not rise fare above 30kV. The charging peak to peak amplitude is raising with decreasing charging current. Therefore watch the peak to peak amplitude during the complete charging. The experience show, that an input peak to peak amplitude of 30V is rquired and a frequency of 2.5kHz is a good operation condition. For further charging, it is not needed to turn down the amplitude, if it was OK short time before, but over longer times and humidity changes, it might increase too far or decrease, so that the charging amplitude has to be increased to reach the full amplitude again.

The discharge is initiated by pushing the bar of the HV-switch in. Because the first spark between the two poles of the switch start already at a distance of 1cm, it should be pushed until the poles touch each another. The measurements on the scope show, that even with slow motion the first spark transfer roughly 90% of the equilibrium charge. This test was done with a voltage of 10kV after the discharge.
BE CAREFUL : Even after the discharge there is still a high voltage of 10kV and more inside the system. Depending of the electronic to be tested, The discharge time is greater than 2min. With the HV-probe connected (1GOHM) the time constant for discharge is 2.3s not accounting for the capacitance of the "customer test electronic". With no ohmic resistivity of the "customer electronic" to ground and consecutive discharges this electronic might collect more charge and the voltage increases above the expectation from a single discharge! It can reach up to the full voltage of 30kV.

Internal circuit

The circuit diagram is documented on the following pages

page 1	Transformers, diode-capacitor-chain, HV measurements ,connections to customer area
page 2	220V power, Relays for charge/discharge control
page 3	Multimeter board
page 4	Help for simulation
page 5	Instructions for setup
page 6	Multimeter (Modification inside the DVM), Help for Simulation

The HV is created in two steps. At first the signal from the external pulse generator is transformed to 1500V peak-peak (top left corner of page 1). In a second stage that sine wave is used as input of a diode-capacitor chain which adds up the voltages of the charged capacitors (middle part of page 1).

For the first stage standard 50Hz transformers from 220V to 15V are used (Schaffer, Type KLF-EN BV-222-0-11232, distributor FARNELL 824-999). They have an isolation voltage from coil to coil of 5kV and the voltage inside each coil is kept below the 230V-rms (= 650V peak-peak). The transformers are tested to be still adequate at 2 to 3 kHz, but not at higher frequencies. At the start of the discharge jumps the current from ground to AC_HV_full from 0A to 0.25A. Because that is impossible through the inductive transformers, relays shorten the primary and secondary coil all the time while not charging (page 2). For sudden discharges during charging diode capacitor combinations provide the current, but do not draw current during charging. The output of the transformer can be monitored with a scope. with a 50Ohm termination the signal is divided by a factor 100'000. The status of the relays is visible by LED's.

The second stage - the diode capacitor chain - charges every 4.7nF capacitor up to the peak to peak voltage 1500V. This is also the maximum voltage each diode can handle. Because of the higher voltage at the first stages (left) there a few diodes are interchanged by 12kV diodes. The 1nF capacitors provide a better charging because the AC-resistivity over each group of 10steps is reduced. They also store most of the charge. Because the charge up voltage up to 10kV their legs are put into isolation material. The rest of the chain is not isolated to ease development and repairs. During discharge to last diode (right) has to handle the current from the top row capacitors to the 30kV-line (0.25A). Some current appears also at the diodes connected to the 1nF capacitors - even that is not expected for an ideal chain. To limit the current from the components at the HV end of the chain through the air to other metal parts this part of the electronics is covered by a plastic box. The DC component of the charging current is monitored on the ground end of the charging chain (middle left of page 1).

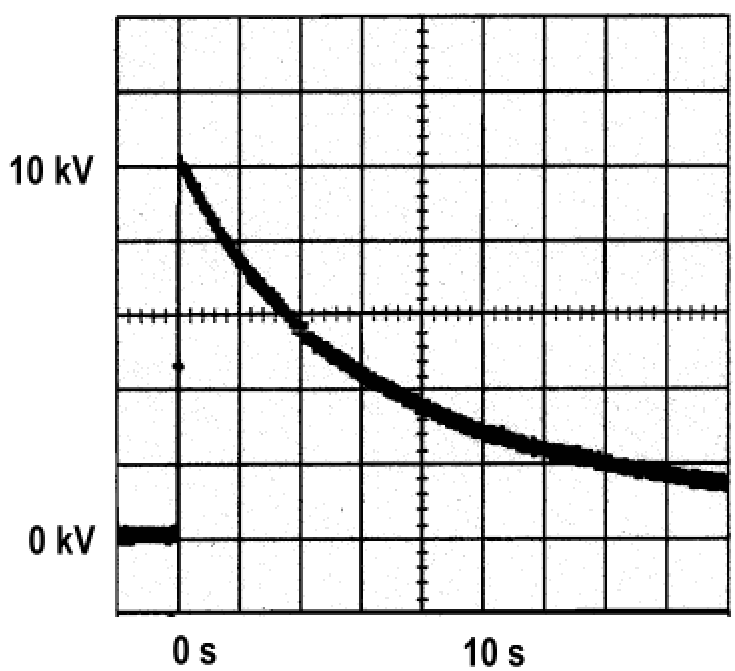
The voltage of the chain is measured by a high ohmic divider (bottom of page 1). A total R of 140GOhm is needed, because the charging current through a 30 stage chain is very limited. A parasitic current from the resistor to ground is avoided by building up a mechanical long chain out of 5GOhm resistors. This chain is covered by teflon and an isolation tube. There are also only a few points where the frame of the instruments supports the isolation tube.

To keep all components with possible high voltage inside the instrument the HV and the charging current are measured and displayed inside the instrument (page 3). The battery powered DVM's are immune against transients on the ground lines. The monitor output of the charging voltage has 480kOhm to the output of the transformers. The internal 820Ohm resistor limits the voltage to less then 200mV, even if the 50Ohm of the scope is forgotten

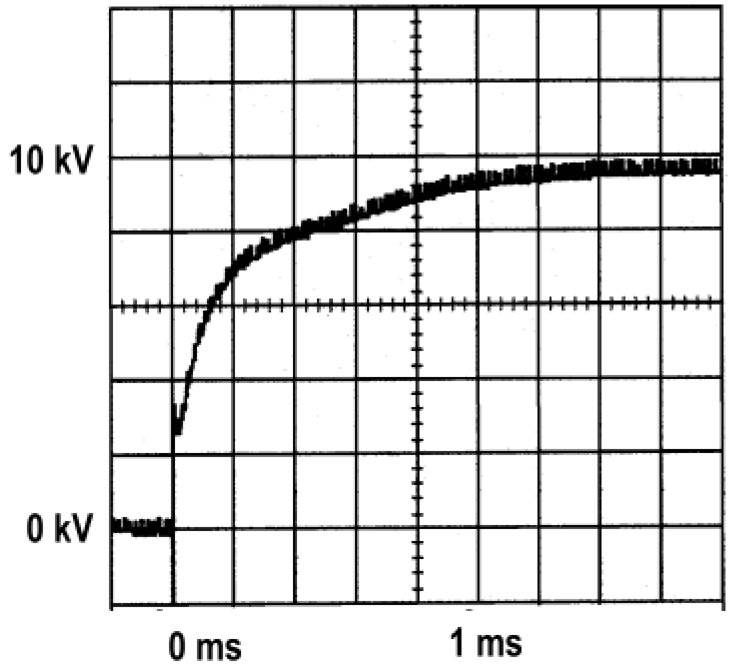
Results from simulation and testing

The 30kV-generator was tested with the DC-DC converter foreseen for the transient recorder. For the description here it is sufficient to replace it by 3nF load between the signal HV_pulse and ground.

The charge transfer from the 30kV-generator into 3nF has been measured. The signal at HV_pulse has been recorded with a 1GOHM HV-probe



Charge transfer from the HV-generator into 3nF. Measured voltage at signal 'HV-Probe'



Charge transfer from the HV-generator into 3nF. Measured voltage at signal 'HV-Probe'

As you see in the figures the charge transfer is smooth (bandwidth of the HV-probe within 3% accuracy is anyway 300Hz. Real bandwidth for 30% decrease is higher). The time constant of the curve is 0.2ms. The expected time constant R*C=60kOhm*3nF=0.18ms and also the 300Hz would convert to 0.5ms. Also the amplitude of 10kV is in agreement with the expectation from the expectation of 11kV.

The total capacitance of the DC-DC converter plus the 30kV-generator (3nF+2.3nF) and the resistor of the HV-Probe 1GOhm describes also the time constant of the discharge of the HV from 10kV to ground: Tau=6s.

Because the HV-chain does not deliver sufficient current to measure the voltages inside the capacitor/diode chain these signals are just simulated. in the time interval from 28ms to 36ms a pre charged chain is charged further. At time 73ms the HV switch is closed. The simulation does not take into account, that the capacitance is voltage dependent. Also the models for the HV-diodes are not tuned.

- Voltage across the first diode (left)
- Voltage across the last diode (right)
- Voltage at the input of the chain (top) and the 30kV-line (bottom) during charging
- Voltage at the 30kV-line during discharging
- Voltage at HV_Probe during discharging
  The simulated signal is slower than the measurement