FT-1230
HERA - DLTS

FT-1235
CGI - Meter

Hardware Manual

2023-03-27

PhysTech GmbH
Hall, DLTS, Customized Physical Measurement Equipment
Am Mühlbachbogen 55d, D-85368 Moosburg
Tel.:+49 (0) 8761 74633 / Fax:+49 (0) 8761 74634
homepage: www.phystech.de **eMail: info@phystech.de**

Content

Introduction..3

1. Measurement Hardware..4

1.1 Pictures and connections..4

1.2 The FT-1230 electronic..6

1.2.1 Picture and description..6

1.2.2 Block diagram..8

1.2.3 Specifications..9

1.3 The FT-1235 CGI-Meter..11

1.3.1 Picture and description..11

1.3.2 Block diagram..12

1.3.3 Specifications..13

1.4 Aux connectors and FET..15

1.5 Calibration..16

1.5.1 Calibration of cryostat offsets..16

1.5.2 Calibration files..17

1.6 Some considerations..18

2. Hardware options..20

2.1 100 Volt option..20

2.2 Fast pulse 20

2.2.1 How the fast pulse interface works 20

2.2.2 Software control..22

2.2.3 Fast pulse generator..23

2.3 Optical excitation..24

2.4 Optical with variable wave length..26

2.5 Sample switch box..27

3. Cryostat and temperature controller..28

4. Diagnose..30

4.1 DLTS hardware..30

4.2 Communication..32

5. Helpful theory for the hardware..33

5.1 The capacitance meter..33

5.2 Pulse Shape in a Fast-Pulse Configuration..35

5.2 Pulse Shape in a Fast-Pulse Configuration..35

5.3 Slew rate of standard pulse..37

5.3 Slew rate of standard pulse..37

5.4 Oscillations and overshoot of pulse..37

6. Index 38

Introduction

This part of the DLTS manuals explains the hardware, its specifications and options. The calibration of the electronic and Boonton bridge will be described in chapter 1.5. If this calibration was not done, you get a hint at the program start.

This manual is the 1. part of the main DLTS documentation set:

1) **Hardware manual H** (this manual)
2) **Installation manual I**
3) **Software manual S**
4) **Basics manual B**
5) **Theory manual T**

The installation of the software will be described in the Installation manual.

1. Measurement Hardware

1.1 Pictures and connections

Our newest DLTS system FT-1230 uses our **CGI**-Meter FT-1235, also developed by PhysTech. We call it CGI-Meter because it measures the capacitance **C**, the conductance **G** and the current **I**. The CGI-Meter includes a 1MHz capacitance bridge, a curremt ampllifier, a capacitance compensation and a fast pulse interface. The DLTS electronic FT-1230 contains a transient recorder with an ADC, some DAC's and amplifiers, bias source, anti-aliasing filter, CC-regulation, optical and digital interface.

The picture below shows the fronts of the DLTS electronic, of the CGI-Meter and of the fast pulse generator. You see additional the PhysTech test device.
The DLTS electronic has no connectors on the front, only 5 LED's.
The front of the CGI-Meter has 3 BNC connectors (starting on the right):

- **Sample Low:** Blue BNC cable goes to the cryostat or to the test device.
- **Sample High:** Red BNC cable goes to the High sample contact at the cryostat or to the test device (Schottky contact).
- **Pulse gen.:** Yellow BNC cable goes to the Fast pulse generator 'Output' BNC connector on the front. This BNC connector has a yellow ring.

The 5 LED's on the front of the FT-1230 denote states:

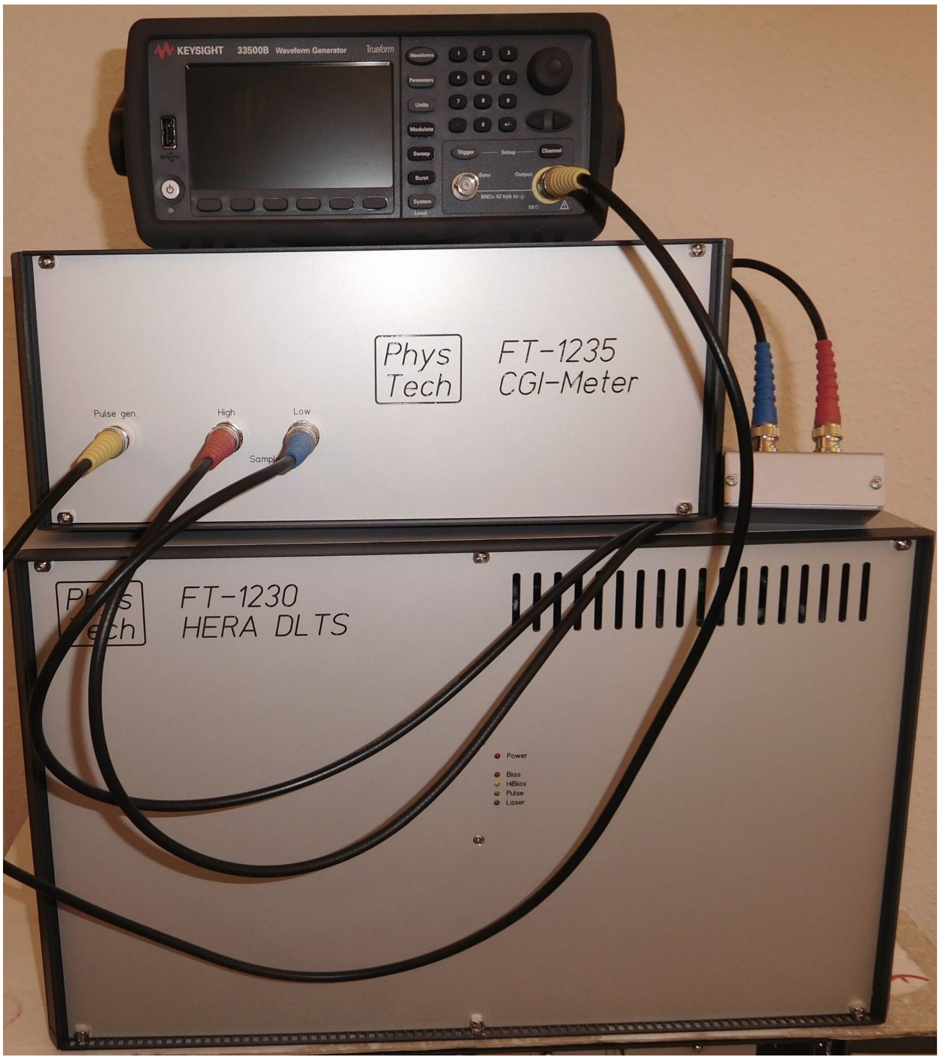
- **Power** – red:
Low intensitiy marks power on, high intensity initialization was done.

- **Bias** – orange:
Bias<>0 is applied.

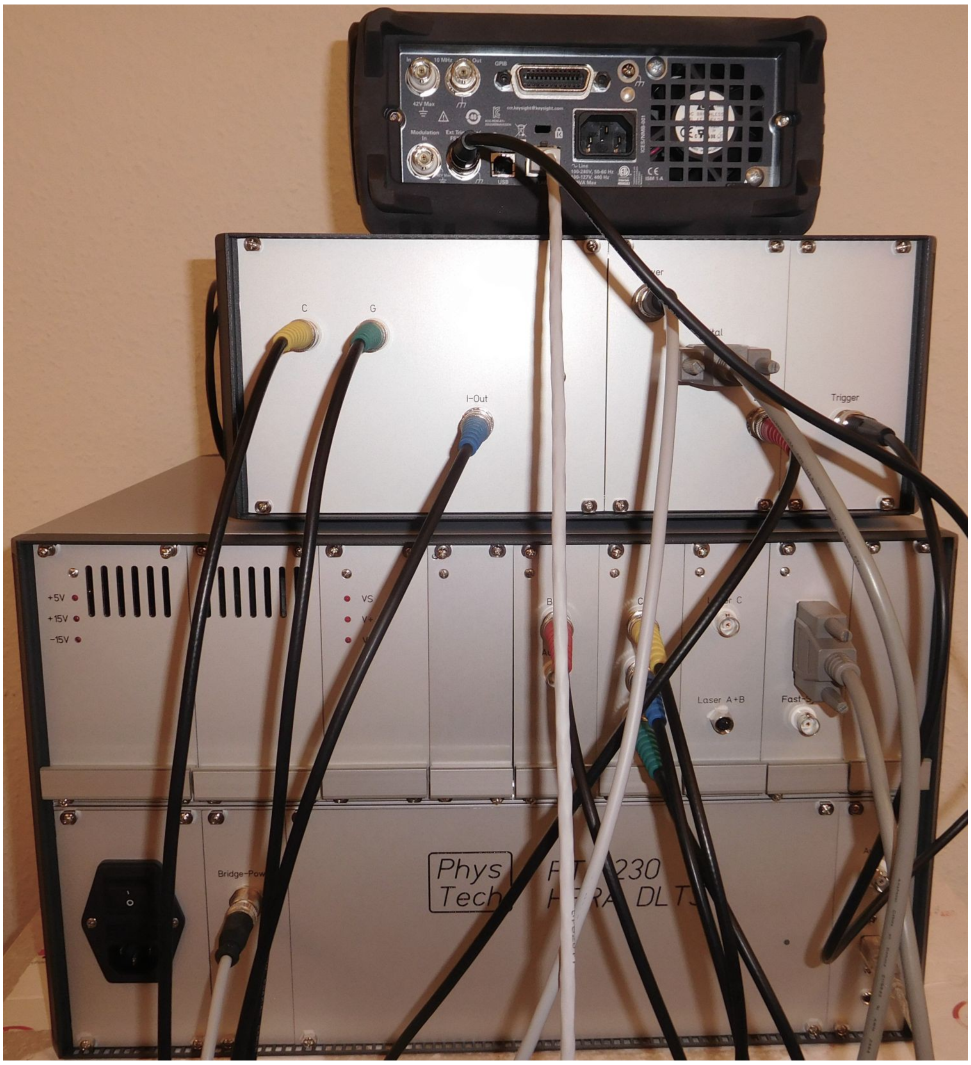
- **HiBias** – yellow:
Low intensity if 100V option is used, bright light if |Bias|>40V.

- **Pulse** – green:
Electrical pulse, means UP on sample.

- **Laser** – blue:
Optical pulse or optical is permanently on.



The next picture shows the rear of the DLTS electronic, of the CGI-Meter and of the fast pulse generator. You see also the cables between these devices.



Following **connections** exist:

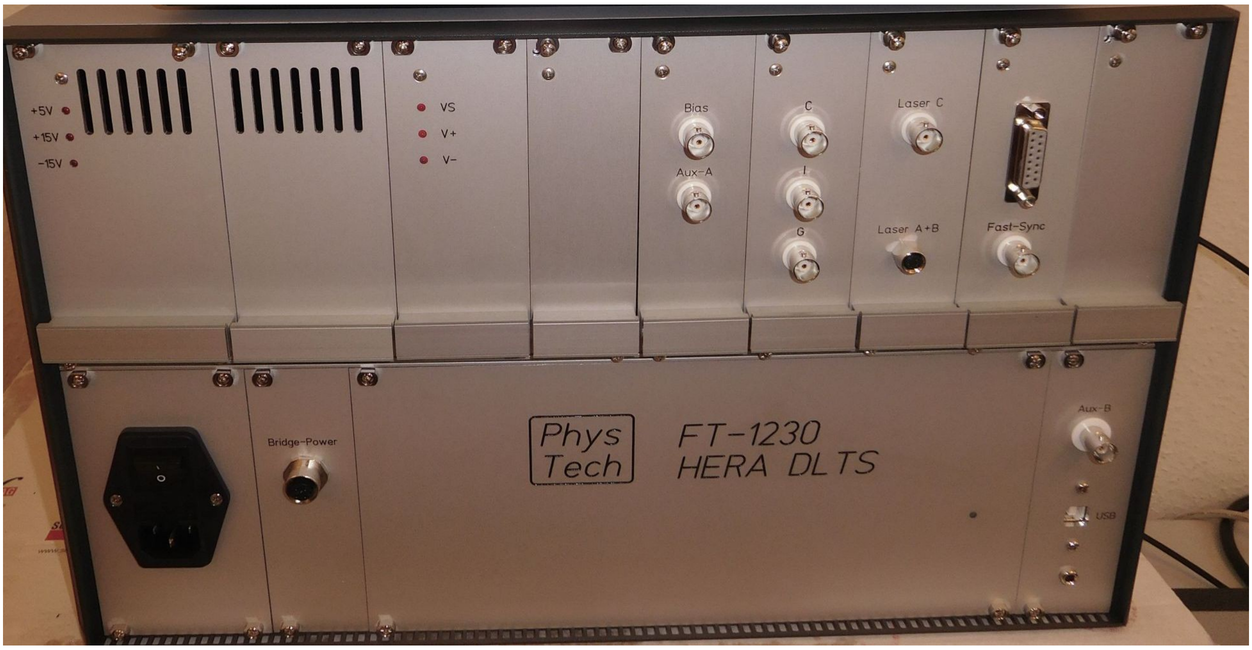
Red BNC cable:	Bias (Electronic)	↔	Bias (CGI-Meter)	- Bias source
Yellow BNC cable	C (Electronic)	↔	C (CGI-Meter)	- Capacitance
Blue BNC cable	I (Electronic)	↔	I-Out (CGI-Meter)	- Current
Green BNC cable	G (Electronic	↔	G (CGI-Meter)	- Conductance
15-pole sub-D	Digital (Electronic)	↔	Digital (CGI-Meter)	- Digital control
5-pole M-12	BridgePower (Elec)	↔	Power (CGI-Meter)	- Power for CGI
Black BNC cable	ExtTrig (Pulse gen)	↔	Trigger (CGI-Meter)	- Trigger for FastPulse

The UDS-voltage (Aux voltage) for FET measurements will usually be connected to Aux-B, see chapter 1.4 for more details.
The Aux-A connector will be used for the sample switch option, see chapter 2.5, or for general purpose defined by the user. Usually it is not connected.

1.2 The FT-1230 electronic

1.2.1 Picture and description

The next picture shows the FT-1230 electronic without connected cables.



The DLTS electronic contains following boards (from left to right side):

- Main **Supply** for 5V and +-15V, 3 LED's:
- **100 Volt** board for the 100V bias (if installed, here not shown).
- **Power** board for 20V or 40V bias and for the NI USB-6351, 3 LED's.
- **Bias** board with Bias and Aux-A BNC output connectors.
- **AmpFilt** board with amplifiers, antialiasing filter, multiplexers and the BNC input connectors for C, I and G.
- **Opto** board for a fix laser and some other options, BNC connector and M8-4pole connector for laser control exist, see chapter 2.3.
- **Digital** board for the control of the boards and of the CGI system, Sync BNC output connector and 15-pole female Sub-D connector.

The **Sync** BNC output is not necessary for the standard FT-1235, only for the USB-version. This signal is an inverted TTL-signal for the pulse (low-active).

On the bottom there are the:

- **Power switch**, connector and fuse.
- **Bridge-Power** female M12-connector for the 5V,+-15V power of the CGI-Meter.
- **Blue light** which shows initialization and activitation of the NI USB-6351.
- **Aux-B** output connector for the Aux-voltage
- **USB-B** connector for the connection to the PC.
- Metal **banana** socket to the case, sometimes black banana connected to the GND. The case is connected to earth but not with GND.

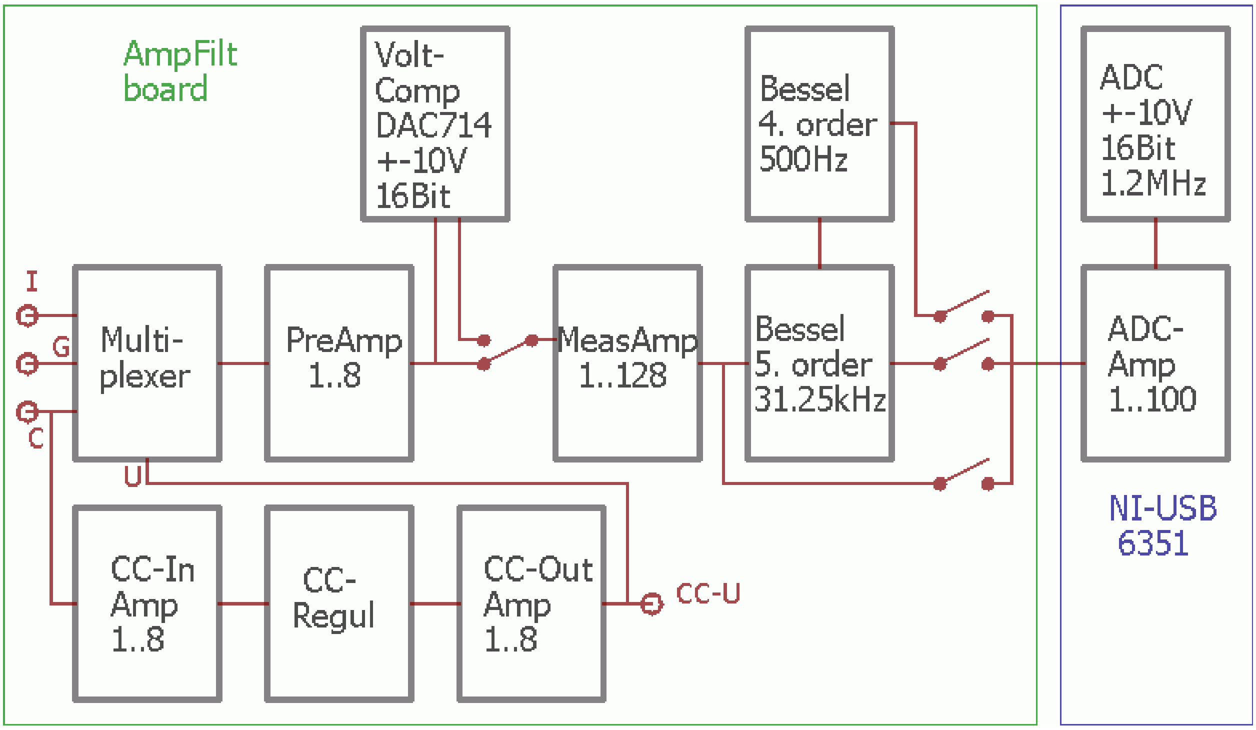
The data acquisition device **USB-6351** from National Instruments is mounted in the electronic case.

Fuses:

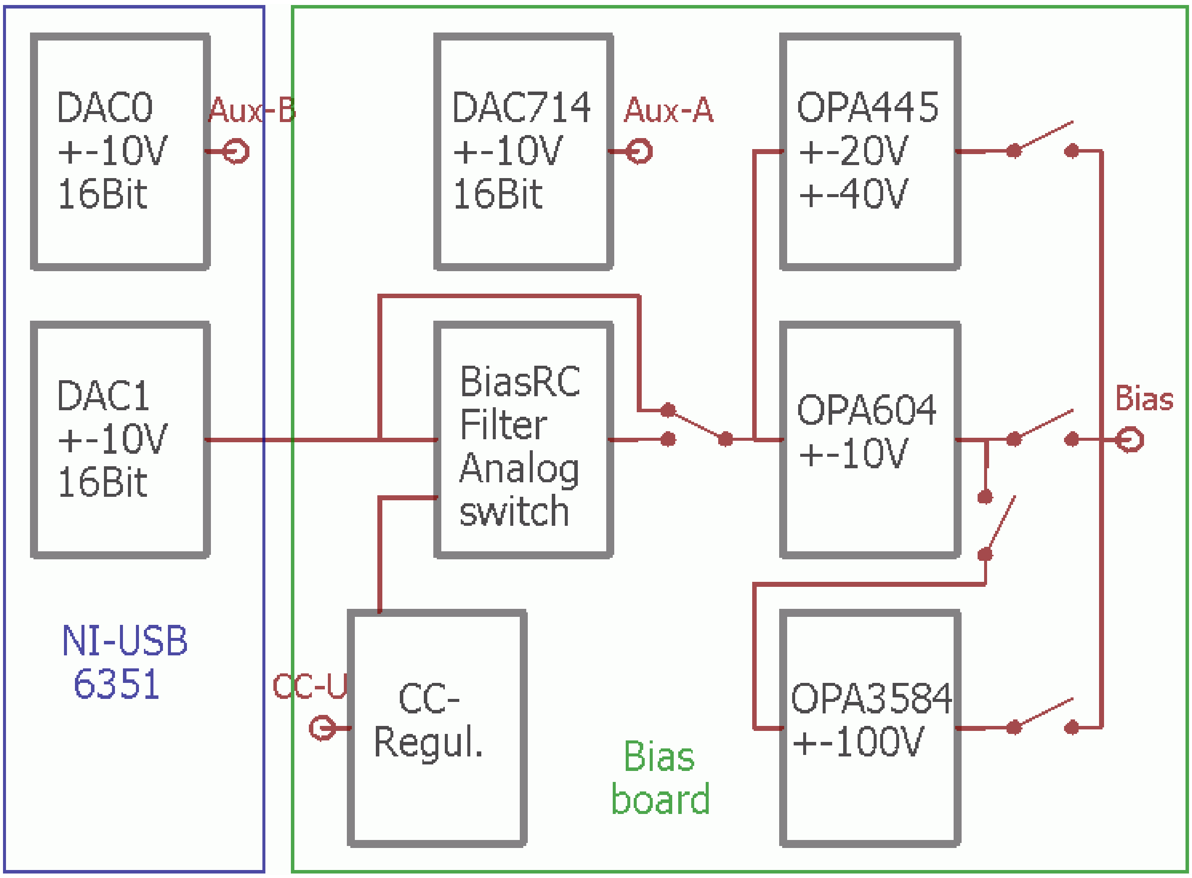
Main power line:	5x20mm, 1AT for 230V resp. 2AT for 115V
Supply:	Round microfuse 1x 1.25AT, 2x 500mAT
Power 23V:	Round microfuse 1x 1AT, 2x 200mAT
Power 43V:	Round microfuse 1x 1AT, 2x 100mAT
100V Option:	Round microfuse 2x 63mAT

1.2.2 Block diagram

The next picture shows the block diagram of the **Analog-Input**:



The next picture shows the block diagram of the **Analog-Output**:



1.2.3 Specifications

Specifications of Analog-Input:

- **A**nalog **D**igital **C**onverter with 16Bit resolution at +-10V, 1 Digit = 0.305mV.
  Minimal (timing) **sampling interval** 850ns (1.2MHz), timing resolution 20ns.
  Maximum sampling points: 1000000 no streaming, 2000000000 at streaming.
- Analog **Anti-Aliasing** filter: 1) Bypass with decrease above 100kHz
  2) 31.25kHz Bessel filter 5. order
  3) 500Hz bessel filter 4. order
- **Amplification** Pre-Amp: 1,2,4,8
  Meas-Amp: 1,2,4,8,16,32,64,128
  ADC-Amp 1,2,5,10,20,50,100
  Total-Amp 1 .. 102400
- **Voltage compensation** with 16Bit ADC, +- 10V for all input signals.

Specifications of recording transient data:

- Minimum numbers of **sampling points** = 32, maximum numbers = 4096
- **Min**imum period width **Tw** = 27.2us
- **Max**imum period width **Tw** = 200s without streaming,
  Tw = 400000s = 111h at streaming
- Standard automatic **working modes**:
  1) ByPass without oversampling
  2) ByPass with oversampling
  3) 31kHz with oversampling
  4) 500Hz with oversampling
  5) 500Hz with oversampling and streaming
- **Digital filter** by oversampling:
  1) No streaming: Bessel 5. order with no phase delay, max. oversampling = 32500
  2) Streaming: Bessel 5. order, max. oversampling = 65000000

Specifications of Analog-Output:

- **Bias** 16Bit, Source = DAC1 of NI USB-6351
  Range 0: +-10V, 1 Digit = 0.305mV, OPA604, 35mA, fastest range
  Range 1: +-20V, 1 Digit = 0.61mV, OPA 445, 15mA
  or +-40V, 1 Digit = 1.22mV, OPA 445, 15mA
  100V-Option +-100V, 1 Digit = 3.05mV, OPA 3584, 15mA
- **Aux-A** 16Bit DAC714, +-10V, 5mA; optional +-20V/40V with OPA 445
- **Aux-B** 16Bit DAC0 of NI USB-6351, +-10V, 5mA; optional +-20V/40V with OPA 445
- **Pulse** with Bias: Pulse voltage as Bias, min. width > 1us,
  max width = 12000s with hardware trigger, >100 h with software trigger.
  Wave form: rectangular, Gauss, specials, arbitrary.
- Output **resistance** of Bias and Aux-A is 100Ohm, of Aux-B 0.2Ohm.

Software specifications of Pulse:

- **Pulse modes** for bias:
  0) No pulse
  1) Standard electrical pulse
  2) DoublePulse, first: electrical, second: electrical
  3) FastPulse, electrical pulse by fast pulse generator
  5) Optical pulse
  6) Electrical and optical pulse together, optional wait time for optical
  7) First: electrical, second: optical, optional wait time for optical
  8) First: optical, second: electrical
  9) First: optical, second: FastPulse
  10) Optical DLOS pulse, 2 optical sources necessary
  12) First: double electrical, second: optical
- **Trigger modes:**
  0) after pulse
  1) during pulse, period width = pulse width
  2) during pulse
- **Disconnect** sample at pulse available
- Hardware and software **trigger** available
- **Auxiliary** (UDS) pulse modes:
  0) No pulse
  1) Only auxiliary pulse, trigger at end of pulse
  2) Only auxiliary pulse, trigger at start of pulse
  3) Before standard pulse
  4) Simultanous with standard pulse

Specification of optical excitation:

- **2 outputs**, 1 for standard laser, 1 additional for DLOS,
  3 connections on 2 connectors (BNC and M8-sensoric)
- **Low/High** active and 5V/3.3V selectable by jumper,
  default maximum current 250mA
- **Pulse width:** Min = 20ns, Max = 12000s at hardware trigger
  Max >100h at software trigger

1.3 The FT-1235 CGI-Meter

1.3.1 Picture and description

The picture below shows the rear side of the PhysTech CGI-Meter FT-1235:

You see following connectors:

- **C** is the BNC output connector for capacitance.
- **G** is the BNC output connector for conductance.
- **I-Out** is the output connector for current.
- **Power** is the 5-pole male M12-input connector for the 5V/+-15V supply voltages.
- **Digital** is the 15-pole male Sub-D input connector for controlling the CGI-Meter.
- **Bias** is the BNC input connector for the bias voltage.
- **Trigger** is the BNC output connector for triggering the fast pulse generator.
- Metal **banana** socket to the case. The case is connected with GND.

1.3.2 Block diagram

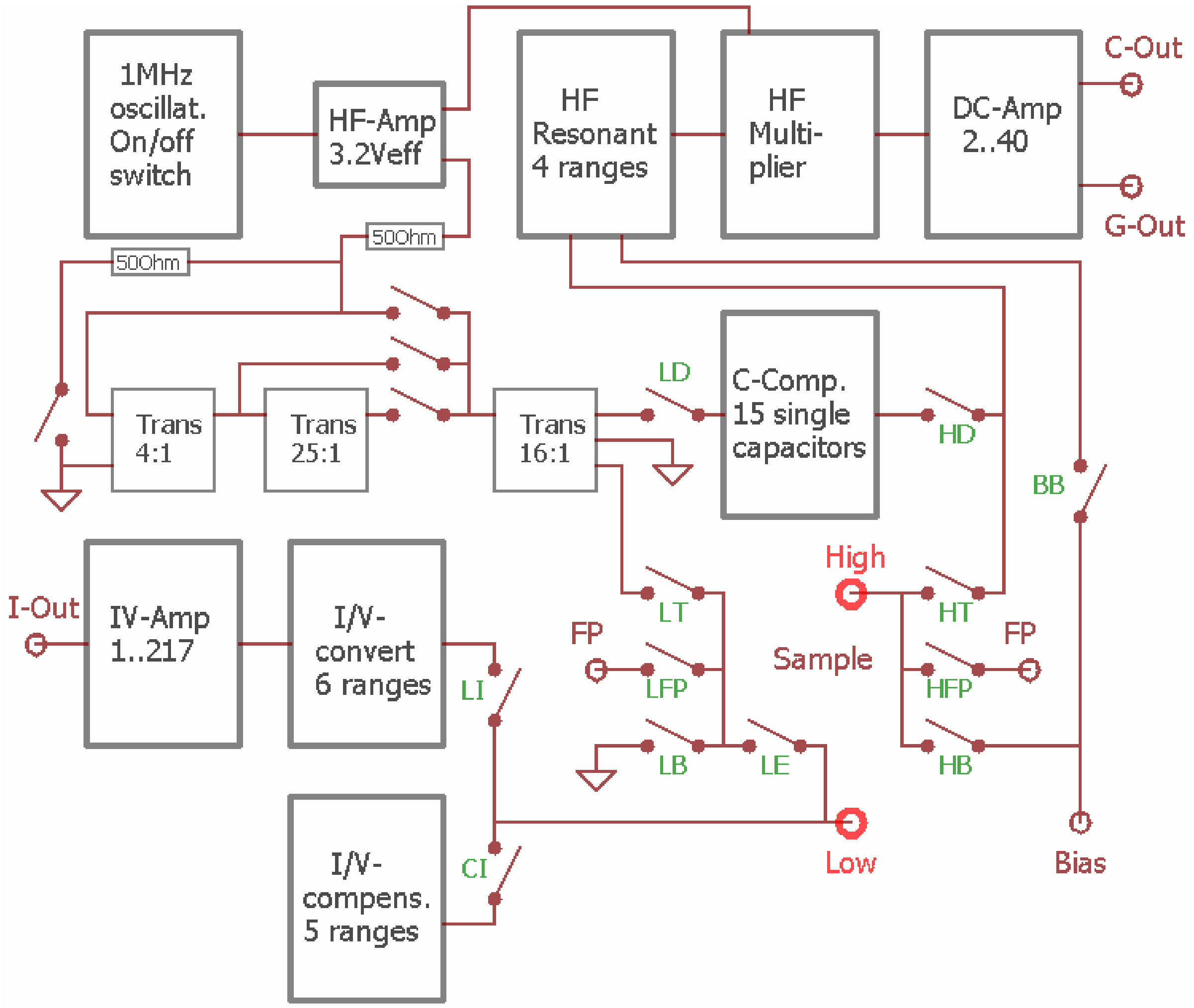
The next picture shows the block diagram of the analog part of the CGI-Meter. You see the four parts of the CGI-Meter:

1) 1MHz Bridge: Oscillator, HF-Amplifier, 3 Transformers for 6 HF-voltages, HF-resonant circuit, HF-Multiplier, DC-Amplifier.

2) C-Compens.: Capacitance compensation with 15 single switchable capacitors.

3) I/V-Converter: I/V-Converter, I/V-Amplifier (up to 217), IV-Compensation.

4) FP-Interface: Relais for switching to different measurement states, FP is the BNC connector to the Fast Pulse generator.



1.3.3 Specifications

Specifications for the 1MHz bridge of the CGI-Meter:

- 4 **capacitance ranges,** 3 range limits:
  1) 4pF, 8pF, 20pF
  2) 40pF, 80pF, 200pF
  3) 400pF, 800pF, 2nF
  4) 4nF, 8nF, 8nF
- 4 **conductance ranges**, 3 range limits:
  1) 4uS, 10uS, 40uS
  2) 40uS, 100uS, 400uS
  3) 400uS, 1mS, 4mS
  4) 4mS, 10mS, 10mS
- 6 **HF-voltages** with following effective voltages and impedances:
  1) 20mV, 0.03Ohm, y, Transformer 1:16, 1:4, 1:25
  2) 40mV, 0.06Ohm, n, Transformer 1:16, 1:4, 1:25
  3) 100mV, 0.8 Ohm, y, Transformer 1:16, 1:4
  4) 200mV, 1.6 Ohm, n, Transformer 1:16, 1:4
  5) 210mV, 3.1 Ohm, y, Transformer 1:16
  6) 400mV, 6.3 Ohm, n, Transformer 1:16

  A 'y' denotes that there is (n=no) a fix 50Ohm resistor between oscillator output and GND. Note that the peak to peak voltages is about 3-times higher than the effective HF voltage.
- **Recovery times** in range 1 / 2, see Notes at end of this capter
  Standard pulse: 500us / 500us
  Fast pulse: 800us / 800us, inclusive relay times
  Disconnect bridge: 700us / 700us, inclusive relay times
- **Phase delay** about 20us
- 2 branches of the 1MHz output, one for the test level (sample), one as difference for the capacitance compensation.
- HF voltage can be switched off during pulse.
- 4 programable amplifications for the DC output of capacitance.

Specifications for the capacitance compensation:

- 15 fix **capacitors** between 1pF and 2.9nF, single switchable by relais
- **Max compensation** capacitance 5.8nF
- **Compensation modes**:
  0) Compensation is switched off
  1) On with min. compensation capacitance of 3pF
  2) On with a fix capacitor in the sample branch, min. compensation capacitance of -0.5pF

Specifications of the I/V amplifier:

- 6 **current ranges**, maximum current at +- 10V:
  1) 100nA
  2) 1uA
  3) 10uA
  4) 100uA
  5) 1mA
  6) 10mA
- **Recovery times** in range 1 / 1-fast / 2 / 3
  Standard pulse: 12ms / 4ms / 2ms / 400us
  Fast pulse: 6ms / 1.5ms / 800us / 700us, inclusive relay times
  Disconnect bridge: 6ms / 1.5ms / 800us / 700us, inclusive relay times
- **Phase delay** 10us in range 1, 5us in other ranges
- Internal programable **amplifications**: 1, 7, 31, 217
- Switchable **feed back** capacitor for range 1 for faster recovery
- Bias at bridge may be disconnected for current measurements
- **Relays** to CGI-Meter >1TOhm
- **Current compensation** with 5 ranges, max. current at +-10V:
  1) 1uA
  2) 10uA
  3) 100uA
  4) 1mA
  5) 10mA

Notes: It is not so clearly to define the **recovery time** of a special range, because this value depends on the sample and the pulse. And it depends on the definition at which capacitance or current the recovery stops, means what is the maximum capacitance or current between the end of recovery and the base line. At I-DLTS the recovery times depend directly on the current range.
A small recovery at starting the transient measurement t0 is not a problem at big transient signals, but at small amplitudes you may see the influence of a too short t0. On the other hand, if t0 is bigger than necessary, you 'loose' the first time of the transient. We have pre-defined values for standard applications. You may decrease or increase this value in the software when necessary, see chapter S2.1.2.2 and S6.2.3 of the Software Manual.

We have **defined** the recovery times by the standard test device (Zener diode) with following parameters: UR=-5V, UP=-0.5V, tP=1ms, rectangular pulse. CR was about 30pF, CP=55pF, IR=-50pA.
For the capacitance bridge we have defined that the remaining recovery capacitance, means the difference between transient start value and base line CR, should be smaller than 300aF in range 1 and 2. This is **1/100000** of the CR value.
For the current amplifier we have defined that the remaining recovery current is **1/10000** of the maximum curent of the range. For range 1 this is 10pA because 100nA is the maximum current in range 1.

1.4 Aux connectors and FET

The FT-1230 electronic includes 2 auxiliary voltage BNC output connectors:

Aux-A: The BNC connector is on the Bias front panel. The output comes from a digital analog converter DAC 714 which is located at the Bias board. The DAC has a 16Bit resolution and +-10V maximum voltage, the maximun current is 5mA. Between this DAC and the BNC connector there is a 100 Ohm resistor, so that the output resistance is 100 Ohm.

Aux-B: The BNC connector is in the near of the USB-connector. The output comes directly from the DAC0 of the data acquisition device USB-6351. The specifications are: 16Bit resolution, min/max. Voltage +-10V, 0.2 Ohm output resistance, max. 5mA output current. This voltage source can be controlled by the USB-6351. So hardware triggering, short pulses, various wave forms and combining with other pulses are possible.

The software has 2 logical kinds of auxiliary voltage:

- **Aux** resp. **UDS** for FET voltage at the Drain contact.
- **2. Aux** voltage for general purpose.

The **physicical** outputs Aux-A and Aux-B (voltage sources) will be matched to the **logic** voltages Aux/UDS and 2. Aux. Usually it doesn't matter which physical voltage source will be used for the logical Aux/UDS voltage. Normally the Aux/UDS voltage will be only applied but not pulsed. But if you want to pulse this voltage, then the Aux-B output has the advantage of triggering by hardware. The Aux-A can only be triggered by software. That don't allow short pulses and yields to other restrictions.
Therefor our default setting is **Aux-B = Aux/UDS**. You may select the auxiliary mapping by the Set_Conf program, see chapter I3.3 of the Installation Manual.

The **FET** measurements needs a second voltage, also called auxiliary voltage, for the drain source voltage. So the bias UR is now UGS and the auxiliary voltage is UDS.
The cables coming from the CGI metert (Sample LOW and HIGH) and DLTS electronic (Aux-B by default, or Aux-A) must be connected as following:

LOW (CGI-Meter) → **S**ource of FET
HIGH (CGI-Meter) → **G**ate of FET
Aux-B (FT-1230) → **D**rain of FET

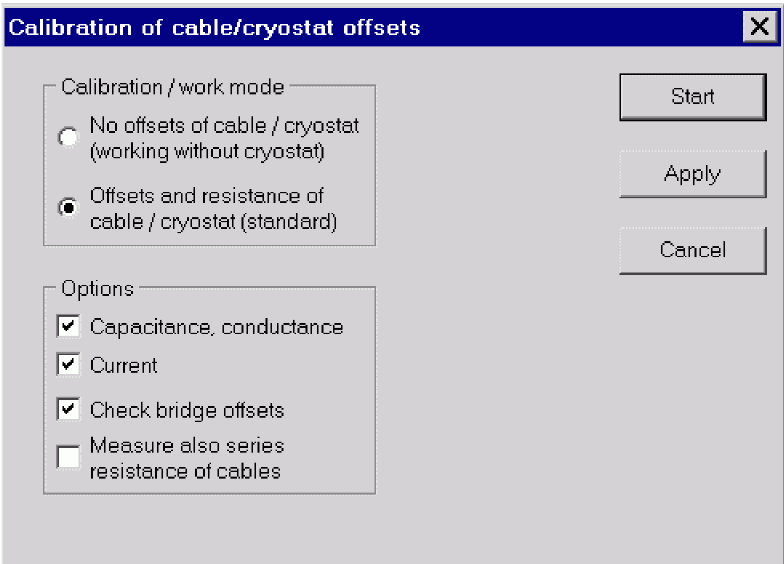
Plesase refere to the considerations above for the aux voltage. It is also possible to swap the Bias- and Aux-cable. Then UR will be UDS and Aux-B will be UGS. You have to tell this the software for the correct labeling of plots and data, see chapter S2.1.2.1 of the Software Manual. Look also in chapter S6.2.5 for FET measurements.

1.5 Calibration

The calibration of the DLTS electronic FT-1230 and of the CGI-Meter FT-1235 will be done by PhysTech. These calibration files are saved in the directory PhysTech\Dlts\Conf\Calib. But the offsets of the cables and of the connections in the cryo system has to be measured at the customer. At program start you get an information to do this if such a calibration was not already done. Initially this calibration will be performed by the Installation Engineer, but it should be repeated when the hardware is changed. It is especially necessary after changes in the cryostat, for example at new isolation or manipulators.

1.5.1 Calibration of cryostat offsets

The calibration is in 'Base tools → Calib → Calibrate cable/cryostat offsets'. After calling this tool you get following input window:



The **work mode** defines whether you want to work without or with the cryostat. In the first case the sample will be connected directly to the CGI-Meter. This is for example for using the PhysTech test device. In this case no calibration is necessary (only Apply button possible).

The **standard** mode is that you use the cryostat. Following options exist for the calibration:

'**Capacitance, conductance**' measures the capacitance and conductance offsets of the cryostat and cables.

'Current' activates the measurement of the current offsets and of the parallel resistance.

'**Check bridge offsets**' checks the offsets of the CGI-Meter alone, means without cables and without cryostat. This is only a check (test), it is not a calibration of the CGI-Meter!

It is possible to 'Measure also the **series resistance** of the cables'. In this case you have to make a short circuit at the manipulator. Don't forget to disconnect the short circuit after the measurement.

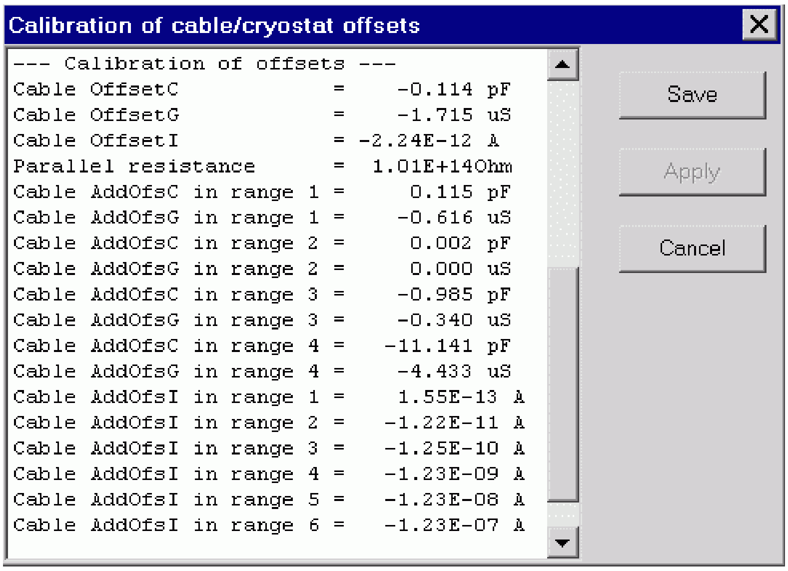
After clicking onto the start button, you get following **instructions:**

- 'Disconnect both sample cables at the CGI-Meter'. It means that the BNC connectors Sample LOW and HIGH at the CGI-Meter are open (not connected with cables). After clicking onto the 'OK' button the offsets of the CGI-Meter will be messured. Note that in this chapter the word 'bridge' means the same as CGI-Meter.
- 'Connect both sample cables to the CGI-Meter and lift (main) manipulator'. That means that a sample must not be connected. An auxiliary connection at the cryostat must also be disconnected. After clicking onto the 'OK' button the offsets of cryostat and of cables will be measured and listed on the screen.

After all measurements are done you see a calibration list as shown on the right.

The calibration values will be saved by the '**Save**' button to disk from which they are used later in the measurements and calculations.

Don't forget to connect all cables and the sample after the calibration.



Note: This calibration is only a calibration of the cryostat offsets. It is not a calibration of the CGI-Meter! That means the bridge itself, the I/V amplifer and the capacitance compensation will not be calibrated here. This will usually done only by PhysTech.
You find procedures for the calibration of the DLTS electronic and of the CGI-Meter in the sub menu 'Service calibrations'. It is only available at user class 6. Don't use it without authorization of PhysTech or of your dealer.

In 'Base tools → Calib → **Service calibrations**' you find some other calibrations for the DLTS electronic and for the CGI-Meter. Usually the customer has not to do these because these were already done by PhysTech. The original calibration files of PhysTech are in the directory PhysTech\Dlts\Conf\Calib. If you make a calibration again, the new or modified file will be saved in the directory PhysTech\Dlts\Work. The original file will not be deleted or overwritten. The DLTS program tries at program start first to find a calibration file in 'Work', then in 'Calib' and at last in PhysTech\Dlts\Sys\Meas.

1.5.2 Calibration files

If you start the DLTS program with the original start option, then only the original calibration files will be loaded. There are no calibrations for the cryostat, only for the electronic and for the CGI-Meter! So use this start option only for testing, but not for working.

Following **Calibration files** (extension is Cfg) exist:

1) **CaliBC**_HHH (CW): Calibration for capacitance of C-Meter
2) **CaliBG**_HHH (CW): Calibration for conduction of G-Meter
3) **CaliBD**_HHH (CW): Calibration of compensation capacitors
4) **CaliIF**_HHH (CW): Calibration of current for I-Meter
5) **CaliVO** (CW): Calibration of DLTS electronic (amplifer, voltages)
6) **CaliBO**_HHH (W): Calibration of C- and G-offsets of cryostat and cables
7) **CaliIO**_HHH (W): Calibration of I-offsets of cryostat and cables

In the list above 'HHH' means the number of the hardware file. A (C) means that the original file with licence number exist in the directory PhysTech\Dlts\Conf\Calib, for example CaliBC_210_299.Cfg for hardware file 210 and licence 299. A (W) denotes that a calibration file done by the customer may exist in the directory PhysTech\Dlts\Work, for example CaliBO_210.Cfg for hardware file 210.

1.6 Some considerations

All the electronic components have been designed for the two applications needed for correct DLTS measurements: The static measurement of the voltage dependance of the sample capacitance and the diode current (C/V and I/V) and the time-dependent measurement of the capacitance or current after a voltage or optical pulse. For the static measurements a very good absolute capacitance (current) measurement is needed for a wide capacitance range. Also the variable bias voltage should be very accurate and cover a wide voltage range with a very good resolution (smallest voltage increment). The time-dependent capacitance transient measurement have to be very sensitive to small capacitance changes with time after a voltage pulse has been applied to the sample.

Amplifier:

This amplifier board includes an input signal multiplexer, an additionally selectable factor (1,2,4,8) amplifier (called PreAmp), the variable factor (1-128) signal amplifier, a voltage compensation and the CC-amplifier. The multiplexer can switch the voltage coming from the I/V converter or from the bridge (capacitance or conductance) to amplifiers. The 'factor'-amplifier can manually be selected using the DLTS software. The amplification factors of the variable amplifier are automatically set by the measurement software of the measurement hardware.

C,I,G,U → Multiplexer → PreAmp → Voltage compensation → Amplifier → Filter → TRC

In **compensation mode** for the capacitance measurement a subtracter and a DAC (called voltage compensation) is available (and used as a standard) to compensate the input voltage to nearly zero before the main amplification is done. This so called **voltage compensation** increases the usable gain of the amplifier during transient measurements. It will also be used for I-DLTS transients.

Filter:

Digital data acquisition systems need a so called anti-aliasing filter. This anti-aliasing filter cuts off all frequencies higher than that ones detectable with the actual setting of the analog digital converter (mathematics: Digital sampling theorem). It avoids the mirroring of high frequent noise into the low frequent (measurement) range. This mirroring is due to the sampling kind of the signal measurement. The used filter is a Bessel filter of 5th resp 4.th order.

Capcitance bridge:

The capacitance meter used for this DLTS system fits to both measurement tasks, static and transient measurements. It can measure capacitance up to 8nF in 4 ranges with quite a good absolute accuracy and gives the possibility to supply a bias voltage to the sample. The output of this capacitance meter is a voltage linear to the sample capacitance. This is measured (amplifier, filter, transient recorder) and transferred to the personal computer. This kind of measurement we call **direct capacitance measurement**.

The CGI-Meter also supplies a difference input. This enables a relative measurement of the sample capacitance (connected to test inputs) against a known capacitance (reference capacitance, connected to difference inputs). The output of the meter is then proportional to the difference between the sample capacitance and this reference capacitance. The big advantage of this capacitance compensation is that the capacitance meter can be switched to a more sensitive capacitance range as it would be possible due to the sample capacitance. Therefor small capacitance changes with time (as needed for DLTS) can be detected much more sensitive. This kind of measurement we call **compensated capacitance measurement**.

Recovery time: The bridge is during the filling pulse in an overload state. In detail, the reason for the overload is not the fill pulse itself but the changed capacitance of the sample during the filling pulse. The bridge will be compensated for a transient measurement at the reverse bias, so the bridge is not compensated during the pulse. The capacitance change is usually so big that the bridge is in overload (out of its range) during the pulse. The bridge needs a recovery time after the fill pulse. We have reduced this time by modification of the amplifier and the phase sensitive detector of the bridge from some milliseconds to about 200us. This time, the phase delay of the bridge (about 30us) and the recovery time and phase delay of the anti-aliasing filter will be taken into account at the measurement and at the evaluation.
We offer a fast pulse option for external pulse generators. The fill pulse will be applied here directly to the sample with bypassing of the capacitance bridge. But this don't change the behavior described above because the bridge is not compensated during the filling pulse.

Bridge overload: If the recovery time is bigger than expected then a small transient with a time constant of several hundred microseconds to some milliseconds may occasionally be observed. This will not be temperature dependent and its net effect will be to introduce an offset into the DLTS spectrum. In this case increment the used recovery time of the software, see chapter S2.1.2.2 of the Software Manual. This effect depends on the sample. To exclude a hardware problem make a measurement with our test device or a commercial Zener diode. Connect this test sample directly to the bridge without the cryostat.

Isolating problems: It can be that the cryostat stage is not correct electrically isolated, see also chapter B4.3 of the Basics Manual. If the isolation is broken (cryostat or substrate) then you get problems with your DLTS measurements. The bad shield yields to an additional capacitance and noisy transients, the sensitivity falls down.
If the DLTS electronic is off, then the resistance between Sample High resp. Low (front of the CGI-Meter) and the shield of the BNC connector must be at least some Mega Ohms. The same is valid for the BNC connectors Bias High and Low on the rear. The resistance between Sample High and Bias High should be smaller than 10Ohm. The same is valid between Sample Low and Bias Low.

2. Hardware options

This chapter describes options which may not included in the standard hardware.

2.1 100 Volt option

This option amplifies the voltage of the standard bias source by a factor of 5 resp. 2.5, so that the maximum bias and pulse voltage is +- 100 V. The maximum current is 15 mA. You have to install a special board in the DLTS electronic.

Exercise care when using the 100 V power supply. The high voltage is very **dangerous**. Remove the bias from the sample before removing the sample.

2.2 Fast pulse

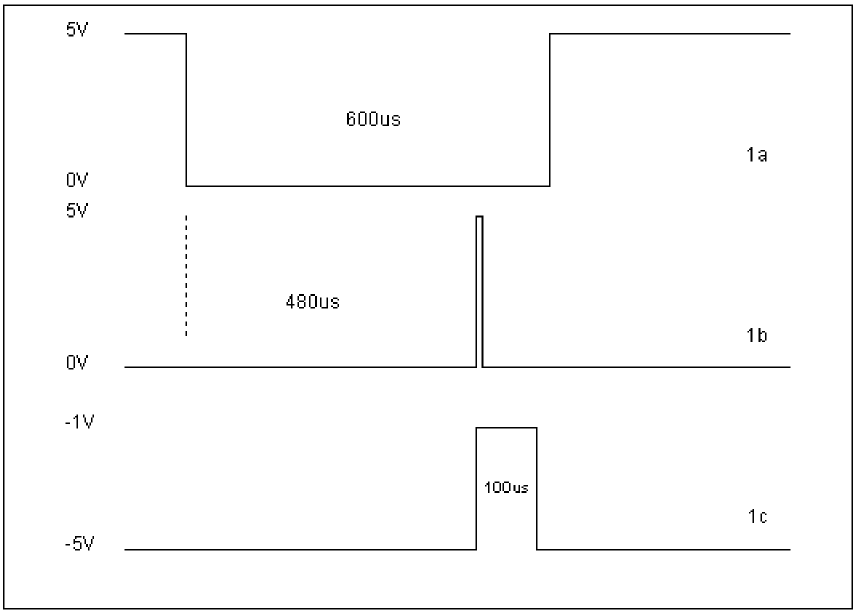
The FT-1235 CGI-Meter includes a fast pulse interface.

2.2.1 How the fast pulse interface works

For 'standard' DLTS measurements the voltage pulse is supported through the CGI capacitance meter to the sample. Due to quite high transducing capacitances the pulse width and the slope is limited. We recommend a minimal pulse width of 20us for pulses through the capacitance meter to the sample. For all faster pulses the pulse has to be set directly to the sample. These pulses can only be supported by an external pulse generator. The internal pulse generator only supports pulses down to 1 micro seconds.
The fast pulse interface switches the sample from the capacitance meter to the external pulse generator, triggers the pulse generator for a single burst and switches the sample back to the Boonton capacitance meter. All switching has to be done that way, that the sample is not disconnected from the bias voltage any time. Therefore e.g. the pulse generator is first switched to the sample together with the capacitance meter and therefore in addition to the internal pulse source of the DLTS electronics. After a short time, the bridge is switched off the sample and the pulse generator is then the only source connected to the sample. In a similar way the pulse generator is switched off and the bridge is switched to the sample.
Work order:

1. Trigger Pulse (TTL) from the DLTS to the FP Interface.
2. The pulse generator is set to reverse bias voltage of the DLTS source and then connected in addition to the bridge (CGI-Meter) to the sample.
3. The CGI-Meter and the DLTS bias source is disconnected from the sample.
4. A trigger pulse is generated from the FP Interface for triggering the pulse generator.
5. A pulse is given from the pulse generator to the sample
6. The CGI-Meter and the DLTS bias source is reconnected to the sample (in addition to the pulse generator).
7. The pulse generator is disconnected from the sample.
8. The transient recorder is triggered for collecting the capacitance transient.

The following shows the **timing diagram** for a pulse width tp = 100 us:



Meanings of signals:

1a: Control signal from measure system = tP + 500 us
1b: Trigger out of interface (Trig) to pulse generator
1c: Input of interface (PgIn) from pulse generator -> voltage of sample

Tip: Look in chapter 5.2 for the pulse shape at small pulse widths.

Note: The internal pulse goes through the capacitance bridge. In opposite to this, the sample is disconnected from the bridge during a pulse of the fast pulse generator. At non standard samples, this may yield to different transients because the 100mV HF voltage is not on the sample during the fast pulse. Additionally the impedance of the internal bias source differs from that one of the pulse generator.

2.2.2 Software control

The DLTS software controls completely the fast pulse interface and the pulse generator. The user has as at the standard DLTS only to input the reverse bias voltage, the pulse voltage, the pulse width and the pulse mode (now fast pulse).

But he should consider followings:

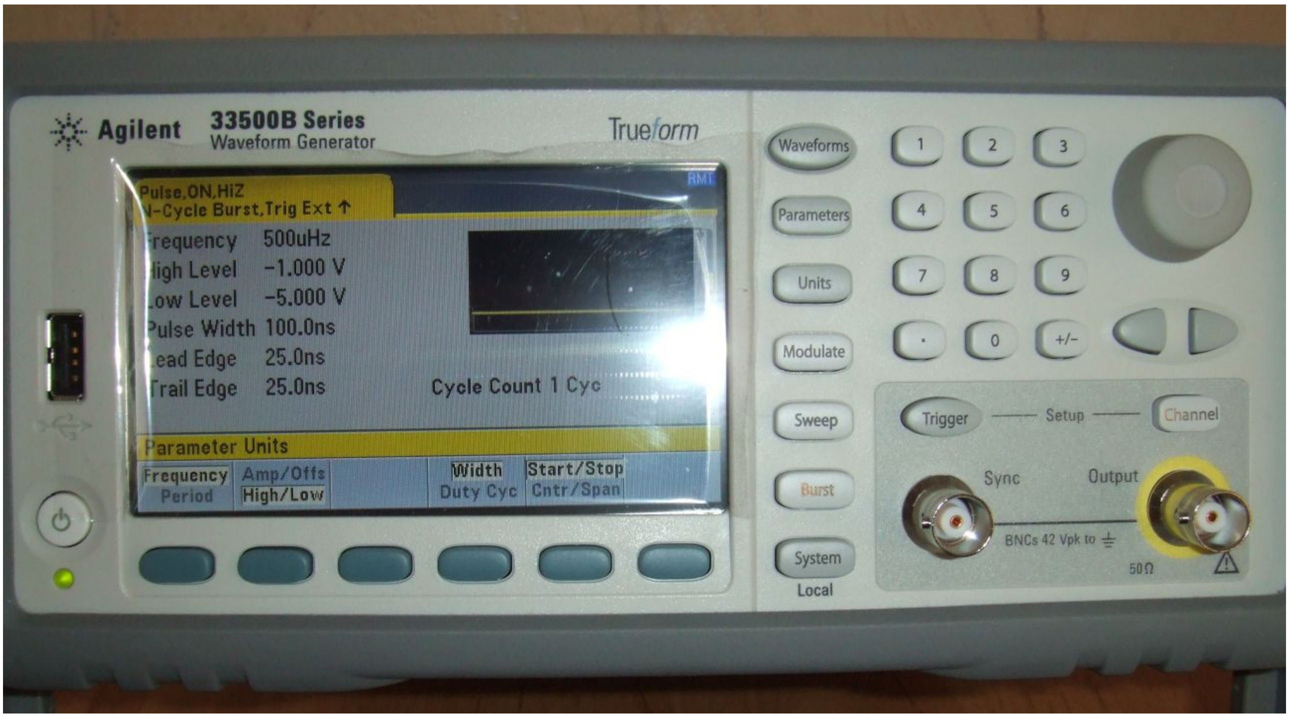
1. After the end of the pulse the system needs an additional recovery time of 700 us before a transient can be measured. This time will be automatically taken into account at the evaluation (t0) and saved into the data files.
2. The useful pulse width and the pulse slew rate is in the practice limited because the samples are not ideal. Usually pulse widths smaller 20 ns can not be completely, that means with the defined voltage, applied on the sample. The pulses reach completely the defined voltages from 20 ns. But the slew rate of the pulses is here also be taken into account. The smallest definable raise time is 5 ns for one edge, but if possible work with edges of 10 ns to avoid an overshoot of the pulse.
3. Based on the different output impedance the pulse generator gets smaller voltages as defined by the user. But the defined voltages (as reverse bias or pulse voltage) are applied on the sample. The different adaption of the sample on the DLTS system and pulse generator will be compensated hereby. Only the 50 Ohm output impedance should be used at pulse generators with variable output impedance (HP81101), called here '50 Ohm into 50 Ohm'.

2.2.3 Fast pulse generator

In many cases we use the 33519B or 33521B (any of 33500 series) fast pulse generator from Agilent. The smallest pulse width is here 16.8 ns and the smallest edge time 8.4 ns. The voltage range goes from -10 V up to +10 V. Because using the 10 kOhm load impedance the voltages shown on the display are the same as from the DLTS system. Depending on the pulse width we use edge times from 8.4 ns to 25 ns.

The output BNC connector on the front (with a yellow circle, see picture on the bottom) must be connected with the PgIn SMB connector of the fast pulse interface. The BNC connector labeled Ext Trig on the rear (right bottom BNC connector) must be connected with the Trig SMB connector on the fast pulse interface.

The next picture shows the front view of the 33521B.



Tip: For viewing the voltages on the front display, it is easier to show high and low level (as the DLTS system) instead of amplitude and offset. For this press 'Local' and then 'Units'. Select in the 2. column 'High/Low'.

Note: Take care of the output level of the old pulse generators HP 8112 and 8116. There this level (5V) will be defined by a regulator on the front panel.

2.3 Optical excitation

The DLTS system can be connected with an optical excitation, for example a LED or laser. The software supports a permanent using of the optical excitation or only during a pulse. Several options for the pulse mode exist. Look in chapter S6.5.3 of the Software Manual for more details.

The Opto board has 2 laser **INPUTS** called 1 and 2. 1 is the standard, 2 is only for DLOS. Each input exist in low and high active mode, so there are 4 inputs:

- **1L**: input 1, low active
- **1H**: input 1, high active
- **2L**: input 2, low active
- **2H**: input 2, high active

The Opto board has 3 **OUTPUT** connections called A, B, and C:

- **A**: Pin 1 of the 4-pin M8-connector, brown cable; output of BC 327 or of 74HC14, selectable by JAS.
- **B**: Pin 2 of the 4-pin connector, white cable, output of BC327.
- **C**: Inner pin of the BNC connector, output of BD438 (higher power) or of 74HC14, selectable by JCS.

Each of the 4 inputs can be mapped to one of the 3 outputs by the jumpers of the 3 connectors **JA**, **JB** and **JC**. By default the blue jumpers are set to: JA=1L, JB=1H, JC=1H.

The jumper **JAS**, between jumpers JA and JB, has a special function. It is for the output A. If the mid and right is connected (default), the output comes from a BC327 transistor. If the mid and left is connected, the output comes directly from the IC 74HC14. The advantage here is that the speed is faster, so that a pulse width of 20ns is possible. And the signal goes really to zero when not active. You can use this mode only for triggering the laser not as power supply. In this mode the active low/high mode is inverted. So here you have to set 1L at JA for active high of INPUT 1.
A similar meaning has the jumper **JCS** for the output C at the BNC connector. It switches between the transitor BD438 output (jumper at TS, default setting) and 74HC14 output (jumper at IC). If using the IC output, then the active low/high mode is inverted. So here you have to set 1L at JC for active high of INPUT 1.

The **output voltage** of the 3 outputs can be changed between 5V and 3.3V by the connectors J6(A), J7(B) and J8(C). Additional the power line, pin 3 (blue cable), of the 4-pin connector may be changed between 5V and 3.3V by J9(P). By default here red jumpers will be set to 3.3V to avoid to demand the laser.

The pins of the 4-pin female **M8-connector** has following meanings:

1: Output A, **brown** cable
2: Output B, **white** cable
3: Power P, **blue** cable (5V or 3.3V)
4: Ground, **black** cable

The orange 2m cable for this connector (M8 sensoric) has 4 wires with the colors described above.

The **BNC** connector has following meanings:

Inner circle: Output C

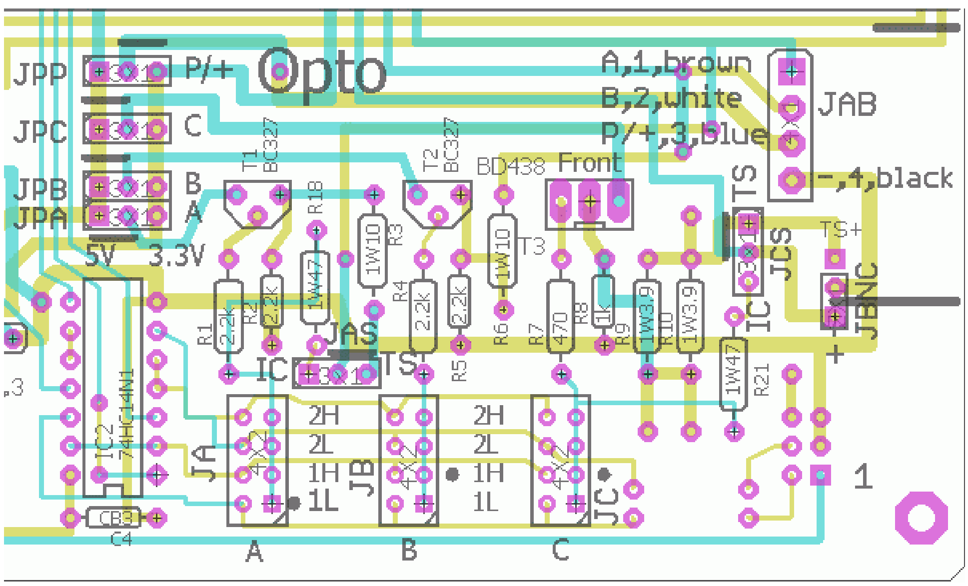
Outer circle: Ground

So by **Default** is valid:

Output A (brown cable):	Laser 1, low active, 5V
Output B (white cable):	Laser 1, high active, 5V
Output C (BNC):	Laser 1, high active, 5V
P (blue cable):	Power, 3.3V

The total **current** is limited to 250mA by a resettable fuse. For higher currents a socket for MIK fuses exist. The maximum current of the 3.3V regulator is 500mA, the 5V of the power P comes directly from the main power supply.
In series to the Laser outputs there is a 10Ohm/1W **resistor** for outputs A and B, and a 2Ohm/2W resistor for output C. The power line is only restricted by the fuse resp. by the 3.3V regulator.

In the following a part of the Opto board will be shown:



2.4 Optical with variable wave length

This option, also called variable laser or **DLOS**, means that you can change the wave length of your optical excitation. It can be a laser, a monochromator with a grid or a series of LED's. The intensity can also be selected if the optical hardware supports this feature. We have no standard equipment for this optical option, the solutions are special for each customer. Ask PhysTech for a special solution, see also chapter I3.3 of the Installation Manual.

One way of adpation is that the commuication between DLTS program and Laser controller will be done via **network**. In this case the customer has to write his own network server program. This program receives commands from the DLTS program and sets then the laser hardware, for example the wave length. For more information look in the file Laser_30.Cfg in the directory Dlts\Sys\Meas. At the end of this ASCII text file you find a description for the server program. A small demo network server can also be started to demonstrate the commands, see chapter I3.3 of the Installation Manual.

Aother way of controlling the laser (monochromator) is the use of a **DLL**. The customer has to write a special DLL which sets the wave length and so on. This DLL will be called by the DLTS software when using the variable laser. You find in Dlts\Sys\Doc\Dll the file LaserS_Ext.dpr which shows the names and parameters of the needed procedures.

As explained in chapter 2.3 the **laser 1** input is for the fix standard laser, **laser 2** input is for the additional variable laser (monochromator). Usually input 1 (fix laser) will be matched to output A (M8-connector) and C (BNC-conector), input 2 (variable laser) to output B (M-connector). The matching may be changed if necessary, but the inputs are fix. Input 1 is always the fix laser, 2 the variable laser.

2.5 Sample switch box

The multi sample switch box option has been developed to measure several samples during one temperature scan. Up to **6** samples can be connected to this option and automatically switched to the DLTS measurement system for transient measurements. The Ohmic contacts of the samples are all connected to the LOW input of the CGI meter. Only the HIGH input of the CGI meter capacitance meter is switched to the particular sample. Only then also the bias voltage and the pulse voltage is supplied to the sample. To all the other samples that are still not selected for a measurement either no voltage (open diode) can be supplied or a collective bias voltage. This bias voltage is supplied by the 2. AUX output (usually **Aux-A** BNC connector) of the DLTS electronics and, when selected, automatically set to the (general) bias voltage value.

The next picture shows the front of the FT-1235 with the additional BNC connectors:

The CGI meter with the sample switch box has on the rear an additional BNC connector labeled 'Aux-S'. It is for the collective bias of all samples, see explaination above. Connect this connector with a BNC cable with the Aux-A connector of the DLTS electronic.
6 additional BNC connectors are on the front of the CGI meter with the sample switch. These are labeled 1 to 6 and are the HIGH inputs for the samples. Connect these connectors with the sample HIGH connectors of the cryostat. If you don't use the sample switch option, see Software Manual, then you have to connect the BNC connector labeled by 'HIGH' at the CGI meter with the cryostat. If you have only one sample it may be better not to use the sample switch option. If this option is deactived, then the use of the standard 'HIGH' BNC connector may yield to smaller parasatic capacitanes. But usually these capacitances are not a problem compared to these ones of the cryostat.

3. Cryostat and temperature controller

The DLTS system works with a lot of cryostats resp. temperature controller. You find a list of supported temperature controllers in chapter I8.5 of the Installation Manual.

The DLTS software must know the **address** of the temperature controller. You can define this address during or after the software installation, see chapter I3.4. There you can also define your minimum and maximum value for setting temperature. Look into your cryostat manual if it is necessary to change the physical address of the temperature controller.

The temperature controllers allow usually control of the **P**roportional, **I**ntegral and **D**ifferential (**PID**) parameters. The DLTS software don't set by default these parameters because of the different environments in which the systems are installed.
So it is necessary to modify the PID parameters manually on your controller after installation to get a good temperature stability. The DLTS software gives the possibility of a temperature test procedure, see chapter S2.4.6.4.

The manual of the temperature controller describes normally how to go about adjusting the three PID controls to achieve an optimum temperature control.

One manual gives following tip:

- Turn initially *I* and *D* off.
- Increase *P* until the heater comes on and leave it until it settles, probably just below the set temperature.
- Then increase *D* gradually until the temperature reaches the set point with minimum overshoot.
- Finally adjust the *I* to remove oscillations.

Some controllers have an **Auto-tune** option for finding good PID parameters. For this set manually a temperature set point, switch the Auto-tune on by the front panel and wait until the controller has found the PID parameters. It saves these parameters in its flash memory. Then switch the Auto-tune option off. Don't use this option during a DLTS measurement.

The DLTS software has the option to support different PID parameters for different temperature ranges, see chapter S2.4.6.3 of the Software Manual.

A good thermal contact is necessary for accurate results of the trap energies. The measured temperature and the 'real' sample temperature differs at a bad thermal contact. See chapter B4.3 of the Basics Manual to avoid this problem.

Error messages of the temperature controller can occur if the sensor (or cables) is broken or has a short-circuit.

Depending on your cryostat it can be that the cryostat stage is not electrically **isolated** and therefore the sample must be mounted onto an insulating substrate, see chapter B4.3 of the Basics Manual. The BNC connectors of the cryostat must have no connection to the shield. There must be no contact resp. a very high resistance between the inner and outer contact of the BNC connector (more than 10 MOhm). You can check this by a resistance meter.

If the isolation is broken (cryostat or substrate) then you get problems with your DLTS measurements. The bad shield yields to an additional capacitance and noisy transients, the sensitivity falls down. The isolation problem can also be visible in C/V and I/V curves. These will be noisy, additionally the effect may change by the voltage.

If you see too much noise or an unusual behavior of static curves or transients make following **checks**:

1. Check the **isolation** by a resistance meter.
2. Use a **known sample** to exclude sample effect.
3. Disconnect the cryostat and use our standard **test device**. This test sample is a commercial 15V Zener diode and comes usually with our DLTS system. Connect the test device directly to the BNC connector on the CGI-Meter. This excludes isolation problems of the cryostat. If you don't have the test device, you can use another commercial 15V Zener diode or a standard diode as the 1N4148. Plug in its wires directly into the BNC connectors of the bridge.

4. Diagnose

4.1 DLTS hardware

If you think there is a problem by the hardware because you see too much noise or an unusual behavior of static curves or transients, make some tests. For all tests starts the DLTS program with the cold start option!

4.1.1 Base check

First you should make some tests which exclude that the problem comes from the sample or from the cryostat. So make following tests:

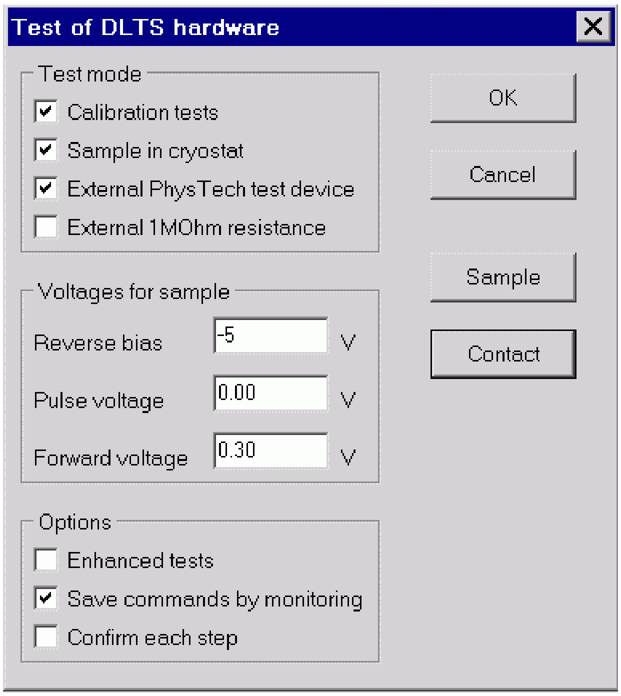
1. Use a **known sample** to exclude sample effect.
   If the measurement is okay, it is an effect of sample and not a hardware problem. One problem could be a too big leakage current, so make an I/V curves with voltages between reverse bias and pulse voltage. Another problem can be a too high serial resistance. This can be an influence on the measured parallel capacitance. In the worst case you get an inverted slope of the transient. If available, measure C/V and G/V curves and calculate the series capacitance and series resistance and the quality Q. Values of Q<1 can yield to errors and problems at DLTS measurements. For more details look in chapter 5 of this manual and chapter S3.1.1.4 of the Software Manual. Chapter B4.1 of the Basic Manual describes how to get a good Ohmic contact.

   If the measurement is not okay, make the next test.
2. Disconnect the cryostat and use our standard **test device**. This test sample is a commercial 15V Zener diode and comes usually with our DLTS system. Connect the test device directly to the BNC connector on the CGI-Meter. This excludes isolation problems of the cryostat. If you don't have the test device, you can use another commercial 15V Zener diode as the ZPY 15 or a standard diode as the 1N4148. Plug in its wires directly into the BNC connectors of the bridge. Set the offset work mode to 'No offset of cable', see chapter 1.5.1 Make then a C/V curve from -5V to 0V and an I/V characteristic curve from -5V to 0.7V. The capacitance of our test device should go from about 30pF to 60pF. Don't forget to set the standard offset work mode after the test measurements.

If both measurements are okay, it is a problem of the cryostat. Check the cables and the isolation as explained in the previous chapter.
If a measurement is not okay, make the 'Test of DLTS hardware'.

4.1.2 Test of DLTS hardware

The easiest way to check the DLTS hardware is to use a special test procedure. Start the DLTS program with the **cold start** option, go to the 'Base Tools' and call there in the 'Calib' menu 'Test of DLTS hardware'. You get first a warning for using the test procedure. After clicking onto the 'OK' button you get following input window with the default setting:



The **Test mode** define which tests will be done:

Calibration tests: The calibration of the CGI-Meter will be checked.

Sample in cryostat: Some measurements will be done with a sample in the cryostat. Please use a known sample.

External PhysTech device: The PhysTech test device, a Zener diode, will be measured. That means measurement without the cryostat will be done. The voltages will be defined by the test procedure.

'External 1MOhm resistance' make measurements at a resistor. Normally this test is not necessary.

Following **options** exist:

Enhanced test are only necessray in special cases.

Usually the measurement commands should be saved by **monitoring** in a file.

If activating '**Confirm ech step**' you have to click onto the 'OK' button after each measurement.

The voltage for your sample in the cryostat will be defined in '**Voltages for sample**'. The 'Sample' buttons opens an input window for sample parameters, the '**Contact**' button opens the 'Test of contact'.

The selection of parameters should be done by requirement of PhysTech. Usually you should use the default settings as shown in the picture above.

After starting the test you get information what to do, means to connect or disconnect sample and cables. At the end you have to confirm in an input window that all tests should be packed in a **ZIP file**. You get also the name and location of this file. Please send this file to info@PhysTech.de.

Note: The word 'bridge' means the same as CGI-Meter in this chapter and in the information box of these tests.

4.2 Communication

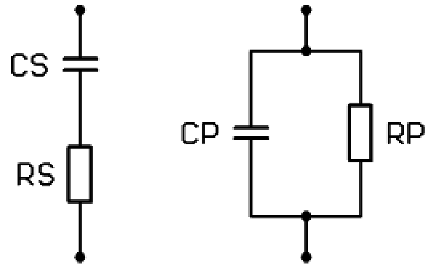
For checking the communication between the DLTS program and the DLTS electronic and the other external devices as temperature controller, there are some **diagnose tools**:

- In the 'Tools' menu of each measurement program module there is the 'Monitor' tool. At user class 6 it is expanded by the tab sheet 'Monitor'.
- You can start the DLTS program with some diagnose options. You find some information in chapter S1.1.3 of the Software Manual and in chapter I6.5 of the Installation Manual.

5. Helpful theory for the hardware

5.1 The capacitance meter

If we neglect the leakage current, a **series circuit** represents the sample impedance, as shown in the left part of the picture. Cs is the depletion capacitance of the diode and Rs the resistance of the diode.
But capacitance meters measure the capacitance of the equivalent **parallel circuit**, see right part of the picture. Cp is the parallel capacitance and Rp the parallel resistance (Gp=1/Rp the parallel conductance) of this circuit.



The **conductance G** is the reciprocal of the resistance: $G=1/R$

The following equations describe the **relationship** between both circuits:

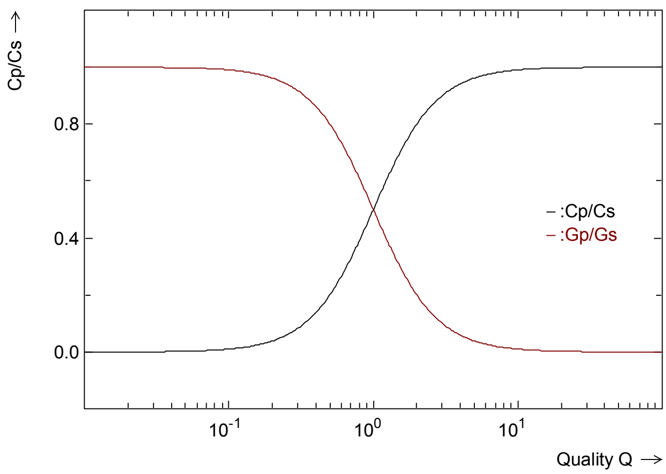
$$Cs=Cp\left(1+Q^{-2}\right) \quad \text{and} \quad Gs=Gp\left(1+Q^{2}\right)$$

Q is in these equations the **quality factor**:

$Q=\omega\, Cp/Gp=\omega\, Gs/Cs$, where ω is the high frequency of the bridge.

The following picture shows the ratio Cp/Cs (black line) and Gp/Gs=Rs/Rp (red line) versus the quality factor Q:

We see that Cp is about Cs for Q>10. If the quality is smaller, the measured capacitance Cp will be smaller than the sample capacitance Cs. The error is more than 50% for Q<1. If the quality is much bigger than 1, the series resistance Rs can be neglected and the measured capacitance Cp is equal the sample capacitance Cs. On the other hand the serial resistance Rs can only be calculated at Q much smaller than 1.



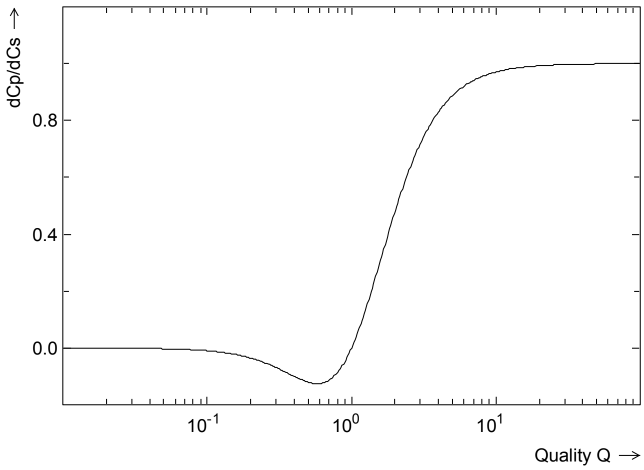
The FT-1235 CGI-Meter allows the calculation of Cs from Cp and Gp, see chapter S3.1.4.2 of the Software Manual.

An influence of the series resistance may be visible not only in the static capacitance values but also in changes of the capacitance, as used at DLTS **transients**. A change of the serial capacitance by δCs gives:

$$\delta Cp = \delta Cs \left(1 - Q^{-2}\right) / \left(1 + Q^{-2}\right)^2$$

The following picture shows the ratio δCp/δCs versus the quality factor Q:

We see that δCp is about δCs only for Q>10. For 1<Q<10 is δCp smaller than δCs but has the same sign. Here the calculation of the amplitude of the capacitance transient and therefor the calculation of the trap concentration is wrong. For Q<1 the sign of the ratio is negative. This yields to capacitance transients (absolute values) which increase instead of decrease with time. This can yield to a misinterpretation.

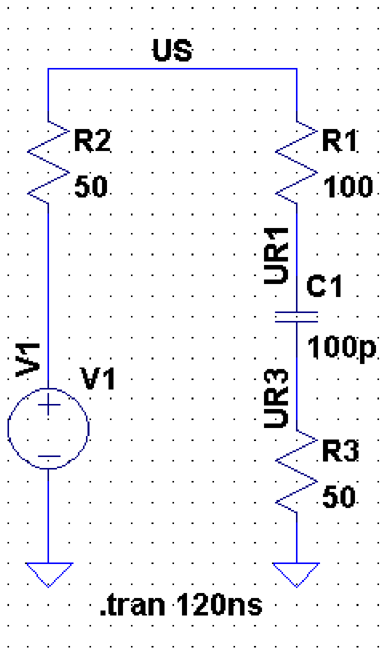


For more information look in: A, Broniatowski et al., J. Appl. Phys. 54, 2907 (1983)

5.2 Pulse Shape in a Fast-Pulse Configuration

The sample voltage during a pulse has not an ideal shape. This is due to real-world limitations which include rise-times and series resistances.

The simplified equivalent circuit diagram of a fast-pulse configuration is shown in the picture on the right, where:



V1: internal pulse source of the pulse generator
R2: internal series resistance of the pulse generator (50Ω)
R3: termination resistor of the fast pulse interface (50Ω)
C1: sample capacitance
R1: sample series resistance

The current necessary for recharging the sample capacitance is given by

$$I = C\frac{\Delta U}{\Delta t}$$, where

C: sample capacitance
ΔU: voltage step
Δt: recharging time (rise-time)

This current leads to resistance voltage drops which reduces the effective voltage of the sample capacitance during the recharge process.

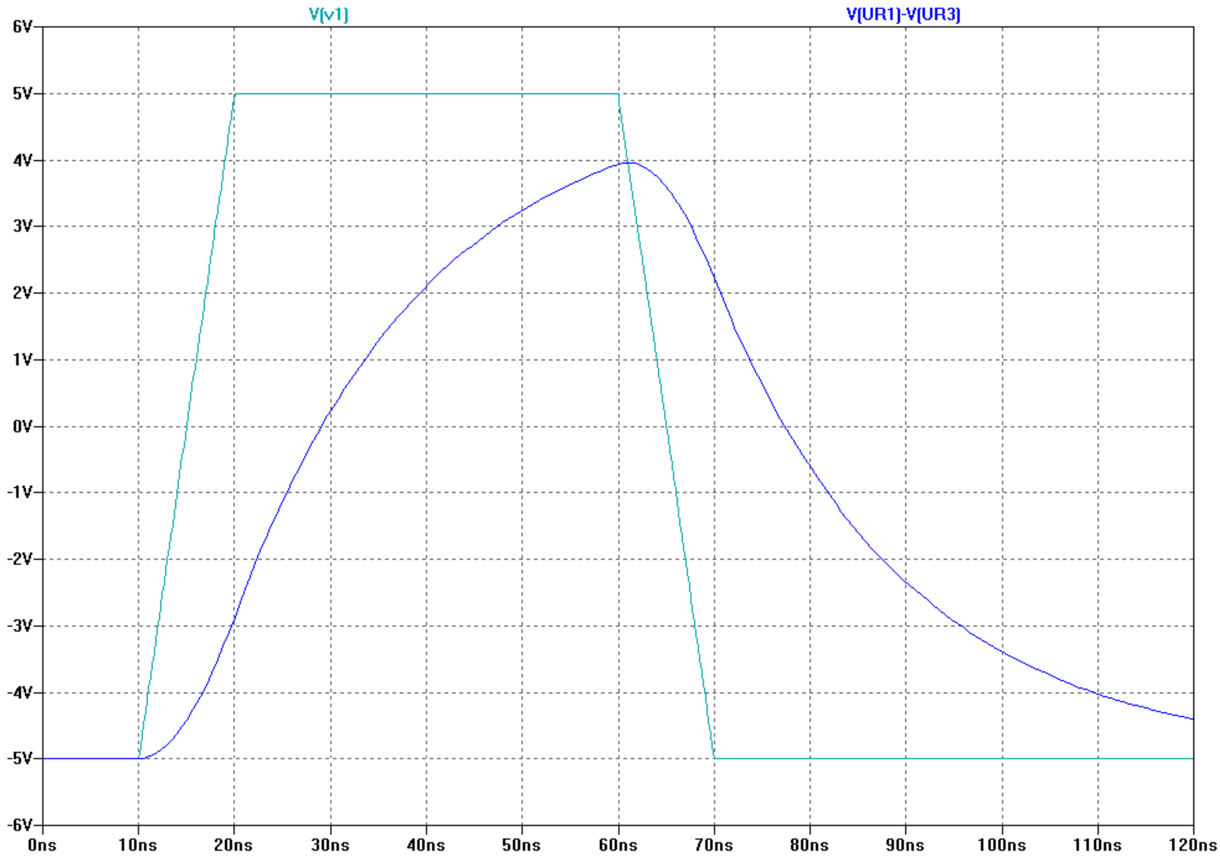
Example: C = 100pF, ΔU = 10V, Δt = 10ns → I = 100mA

The two next pictures show a simulation of the current through C1 and different voltages during the voltage pulse. Following voltages will be shown in the bottom plot:

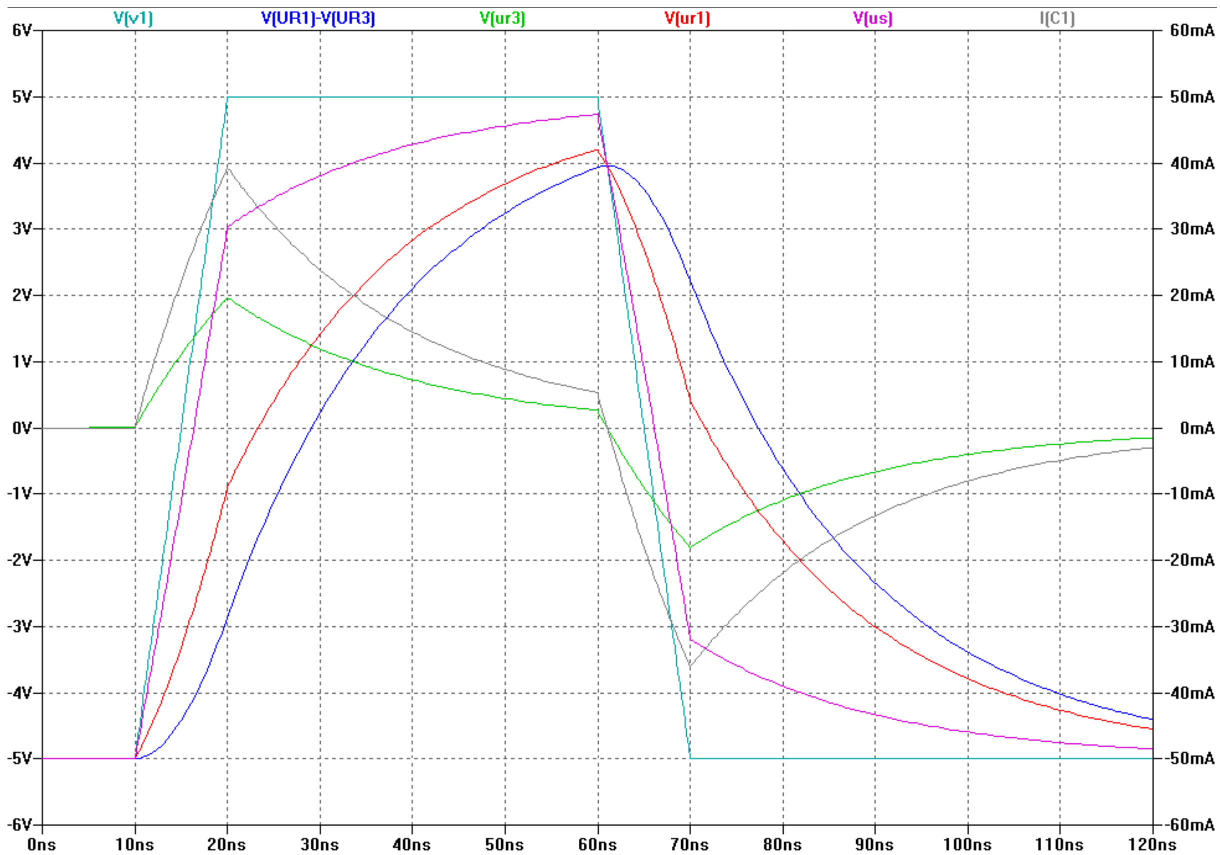
- V(v1): V1 connects V1 and R2
- V(us): US connects R2 and R1
- V(ur1): UR1 connects R1 with C1
- V(ur3): UR3 connects C1 with R3
- V(UR1)-V(UR3): difference of the both signals, means the voltage over C1 (space charge capacitance)

Parameters are: Cs = 100pF, Rs = 100Ω, R2, R3 =50Ω, ΔU = 10V, tr/tf = 10ns, tp = 50ns.

The first picture shows only the 2 most important curves: the voltage of the pulse generator V(v1) and the effective voltage on the sample V(UR1)-V(UR3).
Cs and Rs are the series capacitance and resistance of the sample, denoted as C1 and R1 in the equivalent circuit diagram. tP is the pulse width.
You see, that a pulse width of 50ns is too small for this example. The voltage on the sample don't reach the given 5V and its shape is not rectangular.



The top picture shows the undistorted voltage V(v1) (teal line) and the effective voltage of the sample capacitance V(UR1)-V(UR3) (blue line) versus pulse time. The bottom plot shows additional voltages, see equivalent circuit diagram.



5.3 Slew rate of standard pulse

The measurement 'Check recovery/pulse' of the special measurements in the transient program module enables the observation of the voltage during the normal pulse. Select there the mode 'Pulse', see chapter S3.2.1.6 of the Software Manual. The period width Tw should be bigger than the pulse width tP. Set the capacitance range to 4 and the pre-amplifier to 1, see chapter S2.1.2.2. Connect the High Sample BNC connector of the bridge by a T-connector with the C-input of the DLTS electronic. After the measurement call 'Plot → Transi, select form view' and select then voltage for the y-axis (available at user class 6). Then you should see the last part of the pulse increment (only some points at the start), the plateau (fix voltage) and the decrement of the pulse voltage. The slew rate of the internal pulse generator is about 1 V/us.

5.4 Oscillations and overshoot of pulse

Rectangular pulses may show voltage oscillations and overshoots during the pulse. The overshoot may yield to problems, especially around zero voltage. Look in the previous chapters and in chapter S3.2.1.1.3 of the Software Manual for some pictures. In this chapter special pulse forms will be explained which avoid the overshoot. An analog filter in the bias soucre reduces also the overshoot but increases also the rsising times, see chapter S2.1.2.5 for activating this option.

You find a special procedure for observing this overshoot and oscillations in:

Base Tools → Calib → Service procedures → Test of pulse timings.

Here you can also check the timings of standard and fast pulse. User class 6 is necessary. For this check a BNC T-adapter is necessary. You have to connect this adapter on the BNC HIGH sample output at the CGI-Meter. Connect then on this adapter the both other BNC connectors with the high contact of the sample and with the G-input of the FT-1230 electronic. The voltage (Bias/pulse) will then be measured via the G-input.

You can also observe the pulse by an oscilloscope. Here you have also to use the BNC T-adatper. Connect the sample and the oscilloscope to this adapter.

Note: For observing the real pulse it is important that the sample is also connected (T-adapter). You may use a capacitor of 100pF up to 1nF instead of a sample. If you check it without a sample or if you measure only at the bias output, you don't see the real pulse at a real measurement. You have to measure the voltage through the bridge because the bridge has a big influence to the pulse shape.

An overshoot is also possible at changing the **reverse bias** voltage UR. A setting from -5V to -0.5V in one step yields also to an overshoot. May be that the voltages goes for a short time here in forward direction. By default the change of UR will be done in some voltage steps which avoid this behaviour. You may additionally use a hardware **Bias RC filter**, see chapter S2.1.2.1 of the Software Manual. But this filter has also an influence on the pulse. The rising times are bigger, the overshoot smaller.

Index

ADC....9
Anti-Aliasing filter....9
Aux....9p., 15
Bias....9
Bias RC filter....36
Block diagram....8, 12
Calibration....16
Calibration files....17
Capacitance compensation....13
Capacitance ranges....13
CGI-Meter....4, 11
Conductance....13
Connections....5
Cryostat....27
Current compensation....14
Current ranges....14
DAC....9
Documentation....3
Fast pulse....20
Fuses....7
Hardware test....30
HF-voltage....13
Laser....26
Manuals....3
Monochromator....26
Optical....10, 24, 26
PID parameters....27
Pulse....9
Pulse modes....10
Recovery times....13p.
Specifications....9, 13
USB-6351....7