PPG 512

Programmable Pulse Generator

User's Manual

Document version 2.0.1

Table of Contents

1. General safety information

CAUTION! Before using this device, make sure that you have read and understood the content of this user manual. Store this documentation in a safe and easily accessible place for future reference.

Incorrect handling of this product may result in personal injury or physical damage. The manufacturer assumes no responsibility and cannot be held liable for any injury / damages resulting from operating the device outside of the normal usage defined in this manual.

1.1. Warning symbols and conventions

The following symbols and conventions will be used throughout this manual. Please take time to familiarize yourself with their meaning before proceeding.

	The **general safety alert symbol** is used to alert you to hazards that may lead to personal injury or physical damage. Follow all associated safety instructions to avoid possible injury or death.
	A **high voltage warning symbol** is used to indicate the presence of un-insulated, dangerous voltage inside the enclosure. Note that this voltage may be sufficient to constitute a risk of shock.
	The **laser radiation warning symbol** alerts you that the device can generate laser radiation. Follow all applicable laser safety instructions to avoid injury or damages.
	The device's susceptibility to electrostatic discharge (ESD) is indicated by the **ESD warning symbol**. Ensure that you follow proper ESD protection rules to avoid damaging the device.
CAUTION!	Make sure to follow any instructions prefaced with "**CAUTION!**" to avoid personal injury or damaging the device.
WARNING!	The "**WARNING!**" label prefaces any instructions that shall be followed to avoid severe injury or death.
NOTICE	Important tips and information for device operation that do not include a risk of injury or damage are prefaced with the "***NOTICE***" label.
	This symbol indicates that an earth terminal shall be connected to the ground (to avoid risks of electrical shock).

1.2. Electrical safety instructions

WARNING! The connection of all conductive housings, electrical equipment with a grounded protective conductor and with the main earthing bar is the basis for protection against electric shock (*protective earthing*). Therefor all housings and power sockets must be grounded according to the standards **IEC 60364-4-41:2005 and DIN VDE 0100-410:2007-06** (for Germany).

The technical design for the equipotential grounding, the dimensioning of the cross-sections and the standardized terms are given in the international standard **IEC 60364-5-54: 2011** and the **DIN VDE 0100-540: 2012-06** (for Germany).

Never connect or disconnect any cable while the system is powered ON. This device contains electrical components that are not user serviceable. Servicing of these internal electrical components is restricted to qualified personnel.

Disconnect the power cord from the electrical outlet before performing any maintenance.

2. Introduction

Please take the time to read this manual carefully before using your PPG 512. Make sure that you have understood and follow all electrical safety instructions given in section 1, General safety information.

The PPG 512 is based on a programmable waveform generator (DAC), that permits to generate electrical pulse patterns in a cyclic sequence of 512 bytes. The 512 bytes are stored in a special high-speed memory that can be read out at the full speed of 5 GS/s. This results in a timing resolution of 200 ps per byte (other values possible on request). By loading a data set, arbitrary pulse sequences can be defined with an amplitude resolution of 8 bits (0 to 255). This pre-defined sequence can then be run as a gap less loop at the full speed of 5 GS/s or started and stopped by an external control signal. The output of the internal DAC is amplified feed to the *RF Main* output.

RF Main output:

Main output of the generated pulses. The output must be connected to a 50 Ohm load. Signal output are positive voltage pulses with variable maximum amplitude around +12 V (into 50 Ohm). There is no limitation in maximum pulse duration.

RF AUX output:

Output of pulse reference signal. This is the same signal as on *RF Main* out, but attenuated. Signal output may be as high as +1.5 V into 50 Ohm. Output may be left unconnected or terminated by a 50 Ohm load. Due to high bandwidth, the signal here can be slightly different form the *RF Main* output.

Synchronization output:

A synchronization signal is output by the PPG 512, that signals the full period of all 512 bytes, i.e. every 102.4 ns.

Reset input:

Input may be used to synchronize the pulse generation with external events. If a high level signal (>+3 V) is connected, the read process of the RAMDAC is stopped and the internal counter is reset. A low level signal (<+0.5 V) or no signal connected, lets the device run free. Reaction time may be as long as 100 ns.

NOTICE The internal read cycle of the RAMDAC is generated by a PLL, which does not react to a signal on the *RESET in.* This might lead to an additional jitter in the order of the reading time of one byte, i.e. 200 ps.

OP Mode input:

Input for synchronization with external processes. If no signal or a high level signal (0.75 to 1.1 V) is connected, the RAMDAC is read periodically: i.e. after reading byte 511, reading starts again at byte 0.
If a signal level between 0 to 0.2 V is connected, the reading process will be stopped by the next time the internal counter is reset, i.e. after reading byte 511. Reaction time is around 1 ns.

NOTICE The internal read cycle of the RAMDAC is generated by a PLL, which does not react to a signals on *OP Mode in.* This might lead to an additional jitter in the order of the reading time of one byte, i.e. 200 ps.

Controlling and Programming over Virtual COM-Port:

The PPG 512 can be OS independent controlled over a human readable ascii terminal (Windows: TeraTerm; Linux: Miniterm). For sending waveform data, the interface switches to a special mode with CRC check at the end of transmission. After receiving all 512 bytes the interface switches automatic back to normal ascii mode.

3. Hardware Description

3.1. Hardware interface – operating controls and connections

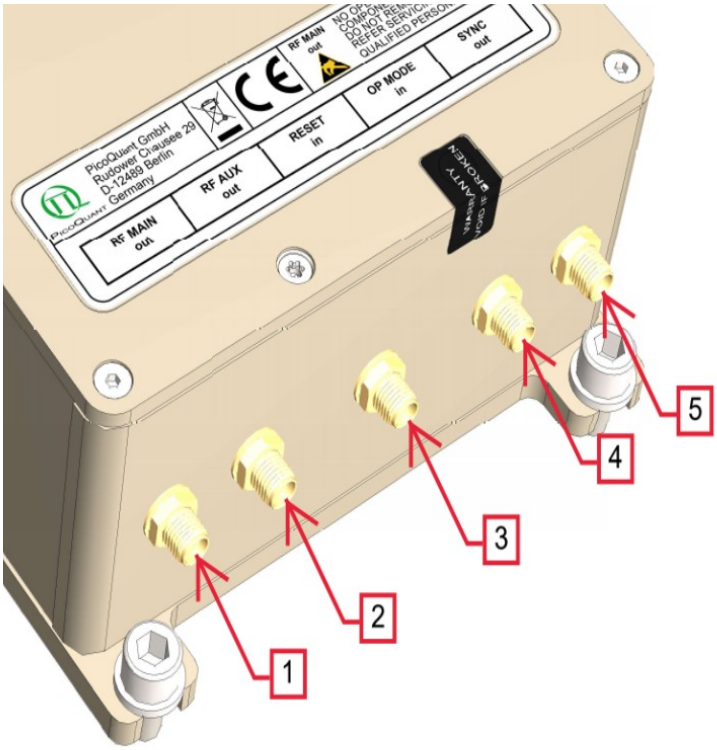

Fig.: 3.1: HF-Panel

CAUTION! In order to generate very fast rising and falling signal edges the *RF MAIN* output has no ESD protection circuit. Therefore take appropriated precautions, i.e. discharge personnel and equipment which will be applied to this port.

1. **RF MAIN**: RF main output.
2. **RF AUX**: Auxillary output to monitor generated waveform.
3. **SYNC**: Synchronization output (see section 5.3).
4. **OP MODE**: OP Mode input (see section 5.5).
5. **RESET**: Reset input (see section 5.4).
6. **STATUS LED**: turns green when Laser emission is ON (see section 4).
7. **USB Type-C**: USB virtual COM Port
8. **POWER**: input socket (Lemo, 2 pin, type 0B) for the power supply DC 12V / 2A.

The **RF MAIN Output** can generate up to 12 V output voltage into 50 Ohm. Under some circumstances like fast rising edges the peak voltage could be higher. Many devices like oscilloscopes can not handle such high voltage directly.

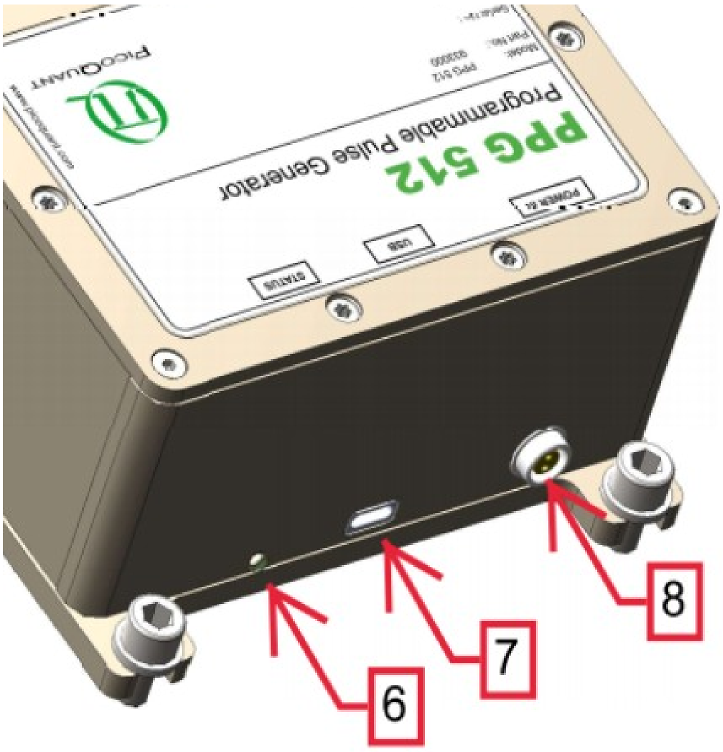

Fig.: 3.2: USB-Panel

3.2. Unused ports

In order to ensure proper Electro Magnetic Compliance (EMC), we recommend plugging an SMA terminator plug (50 Ohms) into any unused output port.

3.3. Heat Dissipation

The combination of high output voltage at the *RF Main* output and a waveform that is most of the time at 0 V generates a lot of power loss within the PPG 512. Like in fig. 7 almost no power is delivered to the receiver, that means, all power has to be absorb by the PPG 512. In this case the PPG 512 may become very hot.

CAUTION! Under some circumstances the PPG 512 may become hot. So only use the PPG 512 with a suitable heatsink and use the lowest VCCRF which is practical.

However the PPG 512 has an internal over temperature detection which puts the PPG 512 in *ERROR* state, when the PPG 512 becomes to hot.

To prevent over temperature the max. *RF Main* voltage should be reduced to a practical minimum by using *SOUR:VOLT:VCCRF* command.

The PPG 512 is designed to conduct heat away from the bottom of the case. So an underground which support these design is recommended. However, an additional fan is built in the PPG 512 to support the cooling and therefore the ventilation holes should not been blocked. The fan can be switched off, but this leads to faster heating.

4. System states

A detailed description of the different states is given in 5.1 .

4.1. POWERUP

- STATUS LED.......................... blinking orange
- UART...................................... print start report
- FUNCTION .... BIST

4.2. STANDBY

- STATUS LED.......................... orange
- UART...................................... waiting for commands
- FUNCTION .... waiting for valid power supply

4.3. WORKING

- STATUS LED.......................... green
- UART...................................... waiting for commands
- FUNCTION .... signal generation

4.4. ERROR

- STATUS LED.......................... red
- UART...................................... waiting for commands
- FUNCTION .... switch everything off
- exit error state only possible with reset (power cycle or reset command)

5. Detailed Description

The block diagram in Fig. 6 describes briefly the data flow in the PPG 512. A microcontroller receives all 512 bytes of the user defined waveform over the USB interface (VirtualCOM-Port). After all waveform data is send a CRC check is preformed. Now the microcontroller loads the waveform data into the RAM of the programmable waveform generator.

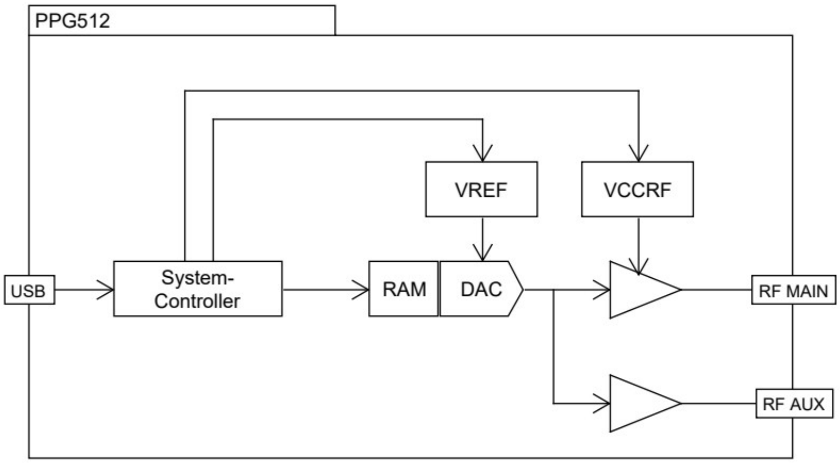

Fig. 1: PPG512 Blockdiagram

The user can control the output amplitude in different ways. Obviously one can program a waveform without using the full bin height. But in this case the dynamic range is reduced. Another way is to adjust the DAC reference voltage *VREF,* it represent the max. possible bin height. So by setting a bin to 255 the DAC would generate a signal as high as the *VREF* voltage. This signal is fed to the amplifiers. By only adjusting *VREF* the dynamic range is maintained. If the signal from the DAC is to high the following amplifiers are overdriven and clipping occurs. Another way to adjust the max. output amplitude at *RF MAIN* is to change the *VCCRF*. With 50 Ω impedance at the output of PPG 512 and the input the receiver the maximum voltage at *RF MAIN* is half the *VCCRF* voltage. *VCCRF* can be set from 12 V to 24 V, which results in max. Voltages at *RF MAIN* from 6 V to 12 V.

If the desired signal is a pulse or a burst of pulses fast rising times the best practice is to set *VREF* and *VCCRF* to its maximum voltages.

5.1. System states

5.1.1. POWERUP

PPG 512 switches from *STANDBY* to *POWERUP* state if a valid power supply is detected and runs a build in system test (BIST).

If BIST was successful the latest waveform data set is loaded to the RAM and the system enters the WORKING state. Depending on *Reset* and *OP Mode* signal generation starts.

When BIST was not successful the PPG 512 enters *ERROR* state and all power supply is turned off

5.1.2. STANDBY

When only the USB is connected the PPG 512 is in *STANDBY* state. This means that all internal power supply is off and all measured voltages, currents or temperatures are not valid, except the values belongs to the external power supply and the system temperature.

Is a valid power supply attached then the PPG 512 changes to *POWERUP* state.

5.1.3. WORKING

While *WORKING* the PPG 512 is active and signal generation is active. It checks also periodically the internal temperature and the external power supply. If one or both are out of limit the PPG 512 changes to *ERROR* state and turn off all internal power supply and also the laser output.

5.1.4. ERROR

In *ERROR* state all internal power supply is turned off. To exit this state a power cycle or a software reset (UART: SYS:RES!) is needed.

5.2. Write waveform to PPG 512

For writing new waveform data to PPG 512 the interface have to be set to data mode. This is done by sending *SYS:DATA!* The interface responses with *ACK* and now accepts only characters which are used for hexadecimal representation (0..9, A..F, a..f, x).

Now the PPG 512 waits for 512 bytes (waveform) and 2 bytes (CRC). The PPG 512 expects the data in 8 bit hexadecimal form with semicolon as separation character between each bytes. After sending the last character the PPG 512 will respond with *ACK* or *NACK (see Fig. 2).*

CRC checksum is preformed on all 512 bytes which represents the amplitude values. For how to calculate the CRC checksum see 7.2.

Only when the PPG 512 response with *ACK* after the CRC checksum was sent, the new waveform is stored in the nonvolatile memory of the PPG 512 and is loaded to the RAM of the waveform generator. If the transfer was not successful, the previous waveform is still active. To readout the active waveform use *SYS:DATA?*.


```
Tera Term - [disconnected] VT
File Edit Setup Control Window Help
SYS:DATA!

ACK
0x00;0x00;0x00;0x01;0x01;0x02;0x02;0x03;0x03;0x04;0x04;0x05
;0x05;0x06;0x06;0x07;0x07;0x08;0x08;0x09;0x09;0x0a;0x0a;0x0
b;00b;0x0c;0x0c;0x0d;0x0d;0x0e;0x0e;0x0f;0x0f;0x10;0x10;0x1
1;0x11;0x12;0x12;0x13;0x13;0x14;0x14;0x15;0x15;0x16;0x16;0x
17;x17;0x18;0x18;0x19;0x19;0x1a;0x1a;0x1b;0x1b;0x1c;0x1c;0x
1d;0x1d;0x1e;0x1e;0x1f;0x1f;0x20;0x20;0x210x21;0x22;0x22;0x
23;0x23;0x24;0x24;0x25;0x25;0x26;0x26;0x27;0x27;0x28;0x28;0
x29;0x29;0x2a;0x2a;0x2b;0x2b;0x2c;0x2c;0x2d0x2d;0x2e;0x2e;0
x2f;0x2f;0x30;0x30;0x31;0x31;0x32;0x32;0x33;0x33;0x34;0x34;
0x35;0x35;0x36;0x36;0x37;0x37;0x38;0x38;039;0x39;0x3a;0x3a;
0x3b;0x3b;0x3c;0x3c;0x3d;0x3d;0x3e;0x3e;0x3f;0x3f;0x40;0x40
;0x41;0x41;0x42;0x42;0x43;0x43;0x44;0x44;0x450x45;0x46;0x46
;0x47;0x47;0x48;0x48;0x49;0x49;0x4a;0x4a;0x4b;0x4b;0x4c;0x4
c;0x4d;0x4d;0x4e;0x4e;0x4f;0x4f;0x50;0x50;x51;0x51;0x52;0x5
2;0x53;0x53;0x54;0x54;0x54;0x55;0x55;0x56;0x56;0x57;0x57;0x
58;0x58;0x59;0x59;0x5a;0x5a;0x5b;0x5b;0xc;0x5c;0x5d;0x5d;0x
5e;0x5e;0x5f;0x5f;0x60;0x60;0x61;0x61;0x62;0x62;0x63;0x63;0
x64;0x64;0x65;0x65;0x66;0x66;0x67;0x67;x68;0x68;0x69;0x69;0
x6a;0x6a;0x6b;0x6b;0x6c;0x6c;0x6d;0x6d;0x6e;0x6e;0x6f;0x6f;
0x70;0x70;0x71;0x71;0x72;0x72;0x73;0x73;0x74;0x74;x75;0x75;
0x76;0x76;0x77;0x77;0x78;0x78;0x79;0x79;0x7a;0x7a;0x7b;0x7b
;0x7c;0x7c;0x7d;0x7d;0x7e;0x7e;0x7f;0x7f;0x80;0x80;0x810x81
;0x82;0x82;0x83;0x83;0x84;0x84;0x85;0x85;0x86;0x86;0x87;0x8
7;0x88;0x88;0x89;0x89;0x8a;0x8a;0x8b;0x8b;0x8c;0x8c;0x8d0x8
d;0x8e;0x8e;0x8f;0x8f;0x90;0x90;0x91;0x91;0x92;0x92;0x93;0x
93;0x94;0x94;0x95;0x95;0x96;0x96;0x97;0x97;0x98;0x98;0x99;0
x990x9a;0x9a;0x9b;0x9b;0x9c;0x9c;0x9d;0x9d;0x9e;0x9e;0x9f;0
x9f;0xa0;0xa0;0xa1;0xa1;0xa2;0xa2;0xa3;0xa3;0xa4;0xa4;0xa5;
0xa5;0a6;0xa6;0xa7;0xa7;0xa8;0xa8;0xa9;0xa9;0xa9;0xaa;0xaa;
0xab;0xab;0xac;0xac;0xad;0xad;0xae;0xae;0xaf;0xaf;0xb0;0xb0
;0b1;0xb1;0xb2;0xb2;0xb3;0xb3;0xb4;0xb4;0xb5;0xb5;0xb6;0xb6
;0xb7;0xb7;0xb8;0xb8;0xb9;0xb9;0xba;0xba;0xbb;0bb;0xbc;0xbc
;0xbd;0xbd;0xbe;0xbe;0xbf;0xbf;0xc0;0xc0;0xc1;0xc1;0xc2;0xc
2;0xc3;0xc3;0xc4;0xc4;0xc5;0xc5;0xc6;0xc6;0xc7;0xc70xc8;0xc
8;0xc9;0xc9;0xca;0xca;0xcb;0xcb;0xcc;0xcc;0xcd;0xcd;0xce;0x
ce;0xcf;0xcf;0xd0;0xd0;0xd1;0xd1;0xd2;0xd2;0xd3;0xd3;0xd4;0
xd40xd5;0xd5;0xd6;0xd6;0xd7;0xd7;0xd8;0xd8;0xd9;0xd9;0xda;0
xda;0xdb;0xdb;0xdc;0xdc;0xdd;0xdd;0xde;0xde;0xdf;0xdf;0xe0;
0xe0;0xe10xe1;0xe2;0xe2;0xe3;0xe3;0xe4;0xe4;0xe5;0xe5;0xe6;
0xe6;0xe7;0xe7;0xe8;0xe8;0xe9;0xe9;0xea;0xea;0xeb;0xeb;0xec
;0xec;0xd;0xed;0xee;0xee;0xef;0xef;0xf0;0xf0;0xf1;0xf1;0xf2
;0xf2;0xf3;0xf3;0xf4;0xf4;0xf5;0xf5;0xf6;0xf6;0xf7;0xf7;0xf
8;0xf8;xf9;0xf9;0xfa;0xfa;0xfb;0xfb;0xfc;0xfc;0xfd;0xfd;0xf
e;0xfa;0x30
ACK
```

Fig. 2: Terminal output after successfully sending a new waveform. Note that 0xfa and 0x30 (0xfa30) is the CRC checksum.

5.3. Synchronization output

The 50 Ohm synchronization output toggles between 0 and 500 mV. When the address counter reach address 253 the sync output at the *RAMDAC* produce a rising edge and if it reached address 508 the sync produce a falling edge. The sync driver circuit adds some time skew. Also for proper timing keep in mind that different cable length can yield to time shift.

Fig. 3 shows the relation between *SYNC* and *RF MAIN* output. *OP Mode* is left open so PPG 512 is in free-running mode.

The programmed waveform in Fig. 3 consist of:

- Byte 0..253 = 0x00
- Byte 254..508 = 0xFF
- Byte 509..511 = 0x00

NOTICE In Fig. 3 the rising edge of the RF Main tend to overshoot, this is because of the very fast rising times. In signal generation a trade off between overshoot and fast edges had to be made. When the signal mustn't have an overshoot the programmed waveform should have slower edges.

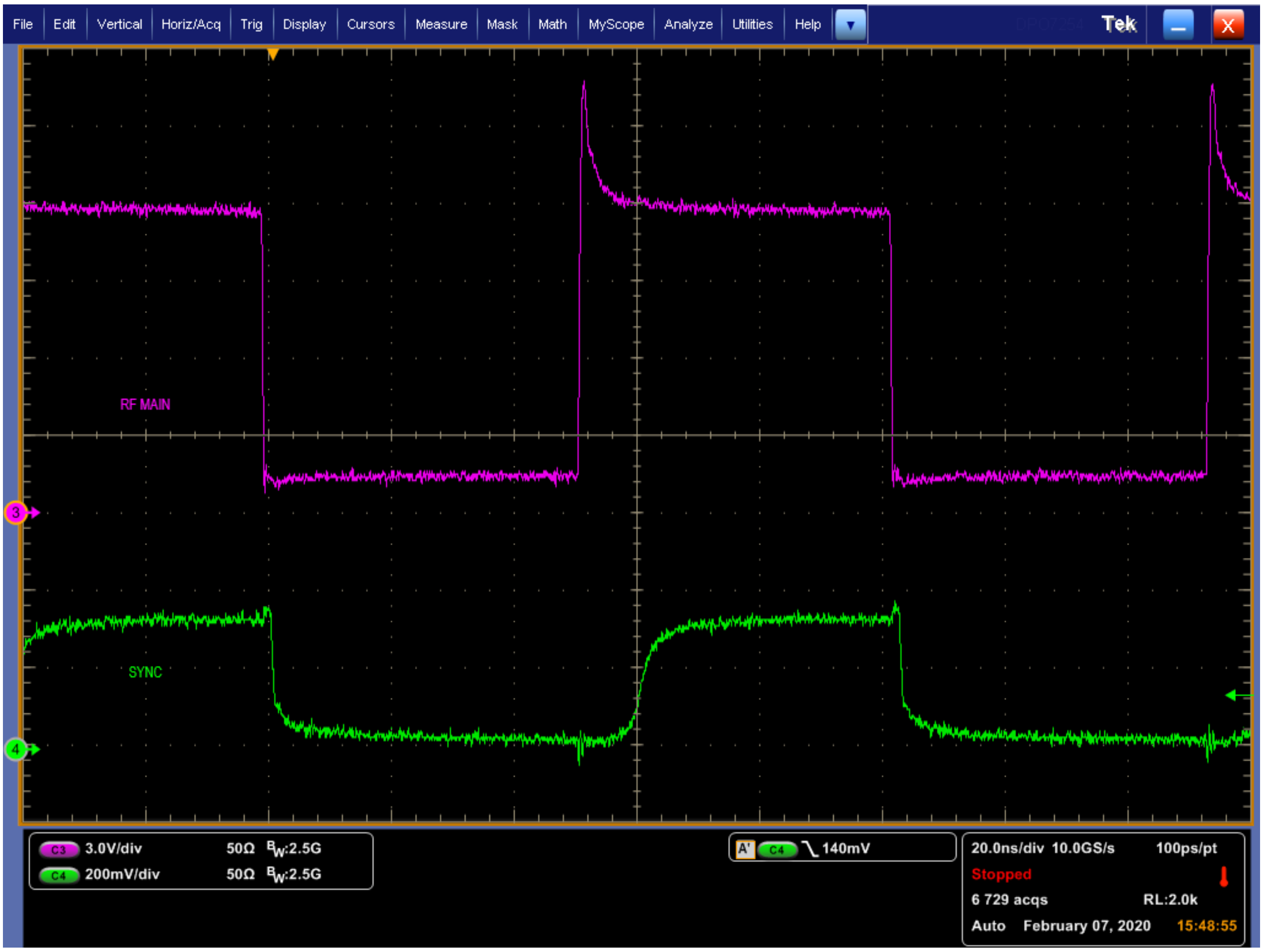

Fig. *3: Relationship between sync and optical output*

Fig. 4 shows a signal without overshoot at the rising edge and Fig. 5 shows the corresponding programmed waveform. The PPG 512 gives the user a great degree of freedom in shaping the desired waveform.

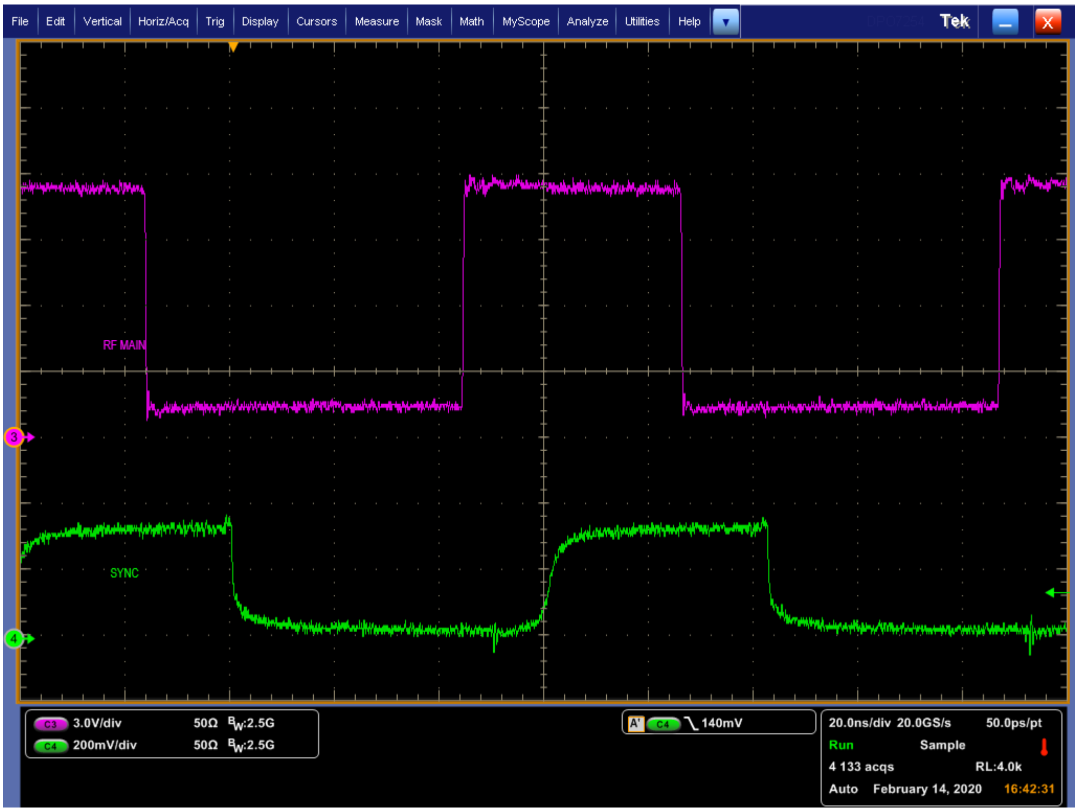

Fig. 4: Square wave without overshoot

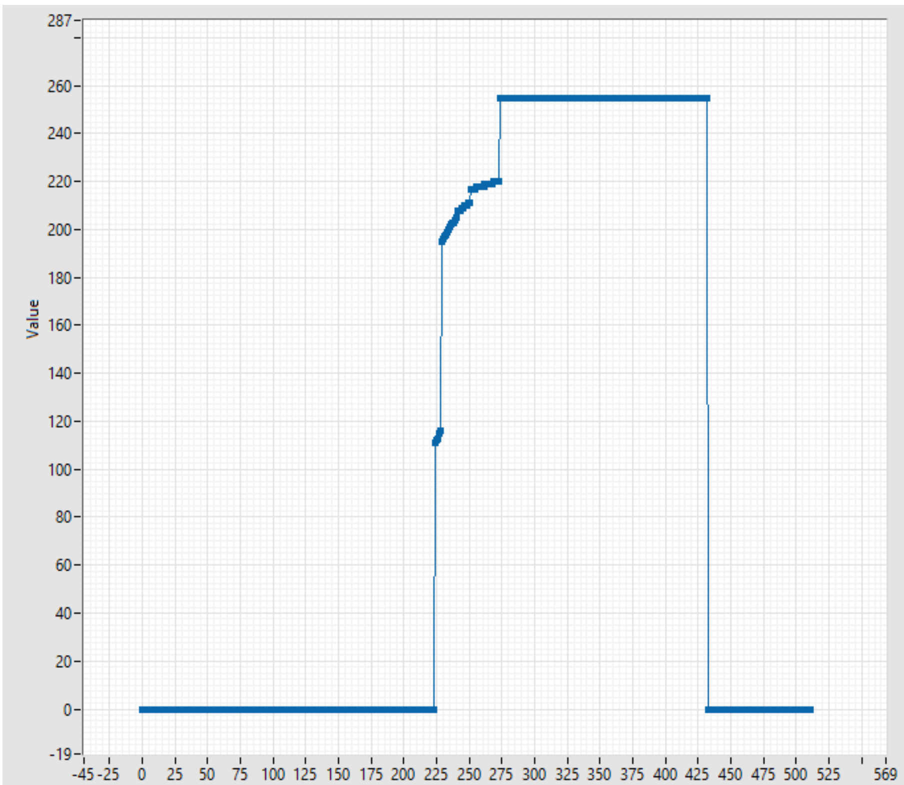

Fig. 5: programmed square wave signal without overshoot

5.4. Reset

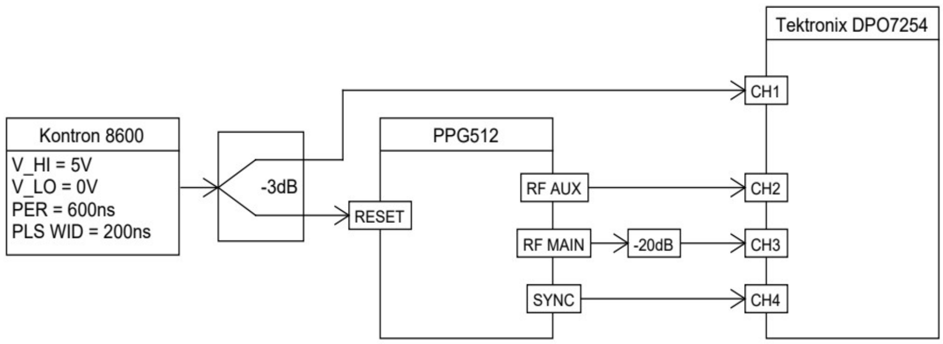

Fig. 6: Reset Setup

The Reset input can be used as a start or restart command. In Fig. 7 is an example given and Fig. 6 shows the measurement setup. The programmed waveform consist of 6x full bin height starting at memory address 100. The reset signal was generated by an external pulse generator (Kontron 8600).

Fig. 7: Reset

To overcome the limitation of the inherent repetition rate of 10.24 MHz of the PPG 512 it is also possible to apply a reset pulse shorter than the 102.4 ns readout time. In Fig. 8 a 50 MHz signal with a duty cycle of 50% is applied to the reset input and fig. 9 shows the programmed waveform. In this particular case, the internal counter never reaches address 253, so no sync pulse is generated.

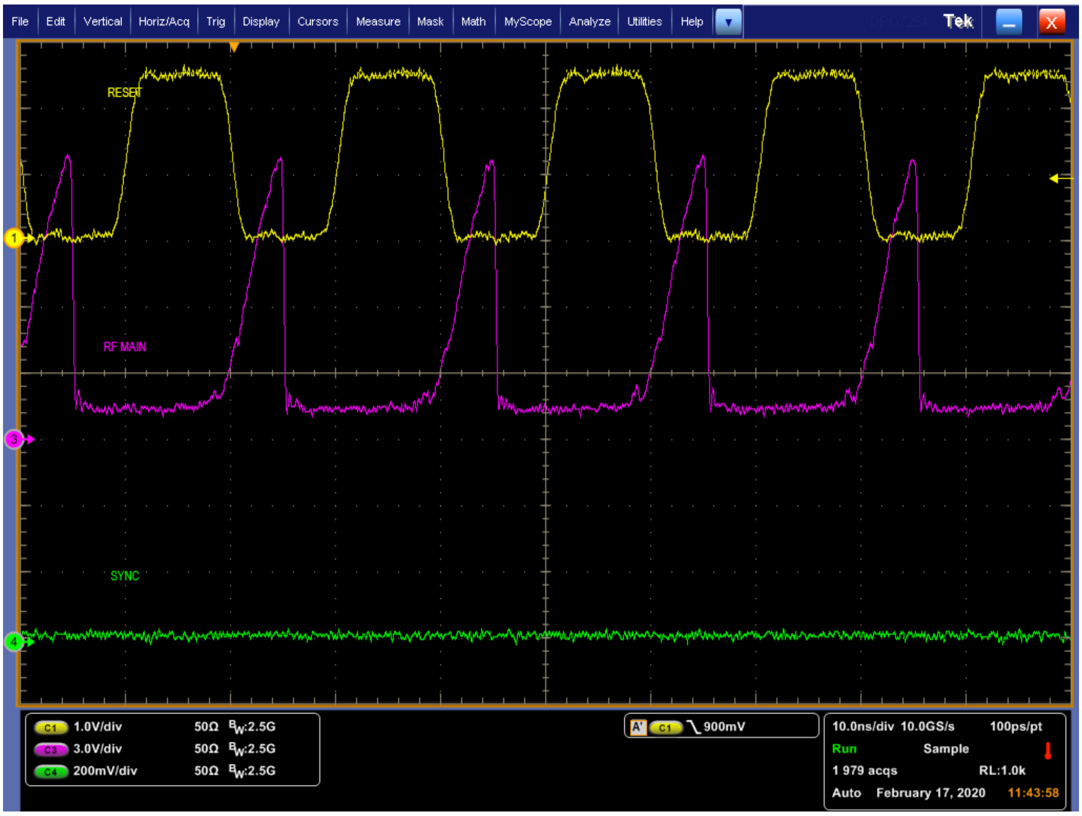

Fig. 8: Rising reptition rate by applying 50 MHz reset signal

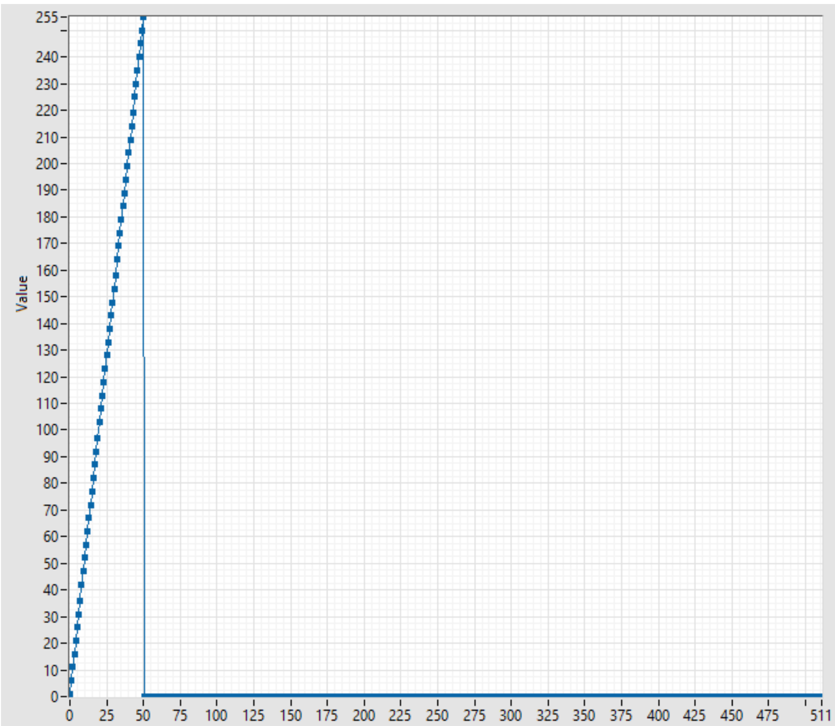

Fig. 9: Programmed waveform for higher rep. rate

5.5. Operation Mode (OP Mode)

The *OP Mode* input is intend for generating a single run or a burst of the programmed waveform. Because of the read cycle period of 102.4 ns the repetition is limited to ~9.766 MHz.

If no signal is applied to *OP Mode* the PPG 512 reads periodically the RAM content, i. e. after reading byte 511, reading starts again at byte 0. This is also true for a high signal (0.75 to 1.1 V) at *OP Mode*.

If *OP Mode* changes to Low (0 to 0.2 V) the reading process will be stopped by the next time the internal counter reaches byte 505. That's why every byte beyond 505 will be not read.

In Fig. 10 burst generation is shown. The signal at *OP Mode* has a frequency of 2 MHz and an on-time of 120 ns, that's why the PPG 512 generates every 500 ns 2 pulses. The programmed waveform consist of:

- Byte 0..10 = 0xFF
- Byte 11..511 = 0x00

For proper operation shift the falling edge of *OP Mode* in the middle of the programmed waveform. I.e. to generate a single run (102.4 ns) select an on-time of 50 ns.

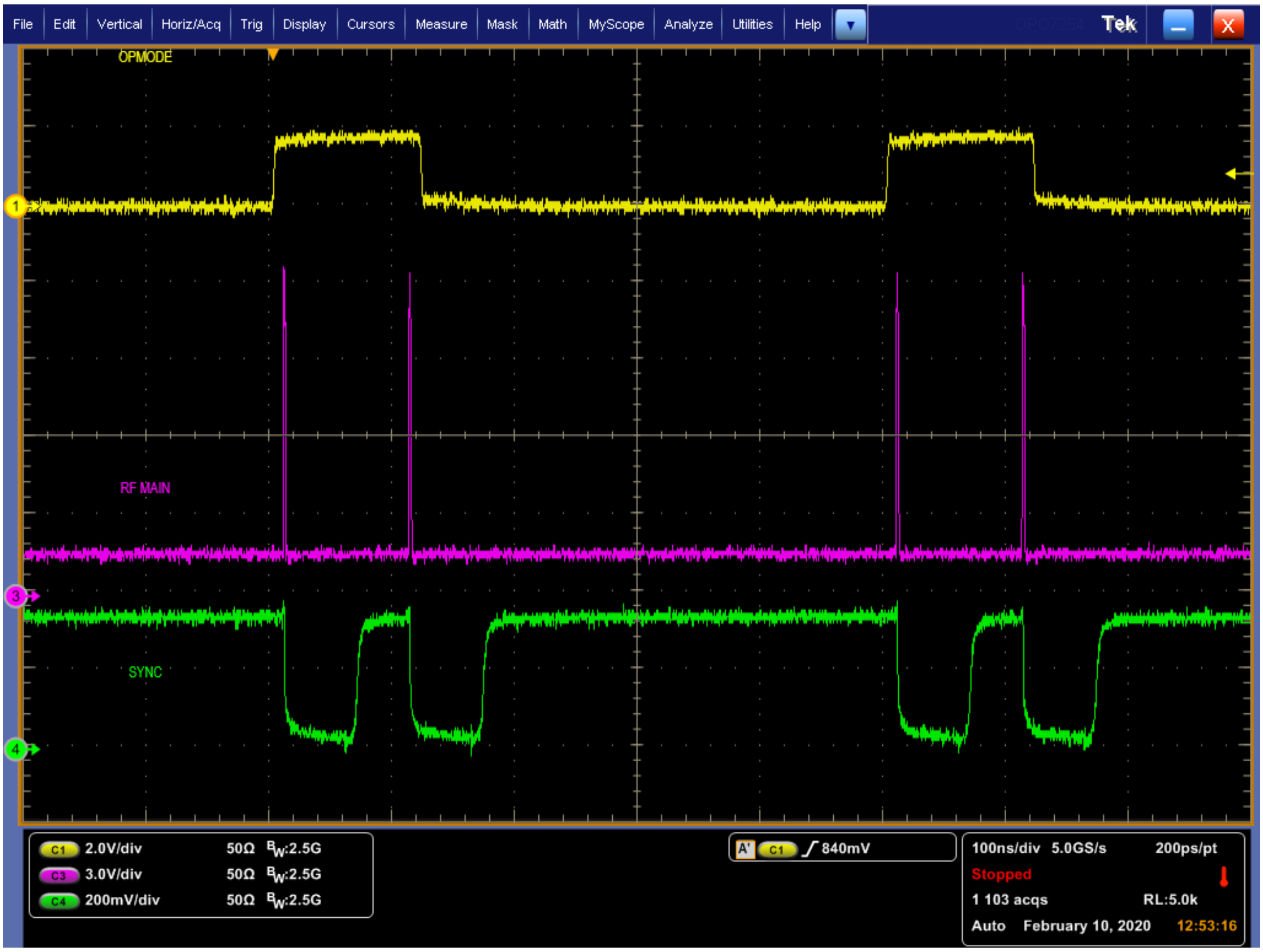

Fig. 10: Op Mode

6. UART-Control Interface

- Use only uppercase letters, numbers and special character '!' and '?'
- single white space is also possible depending on command but not in numerical values
- only use short form (uppercase part) of command
- command processing starts with *newline*
- system response:
  - *BUSY* system is busy and can therefore not handle command
  - *ACK* response for every correct set command (ends with '!')
  - NACK response for commands with wrong parameter
  - *COMMAND UNKNOWN* wrong or misspelled command
- like SCPI systems, the PPG 512 response to **IDN?* with the string "*PPG 512"*

6.1. Command-Tree

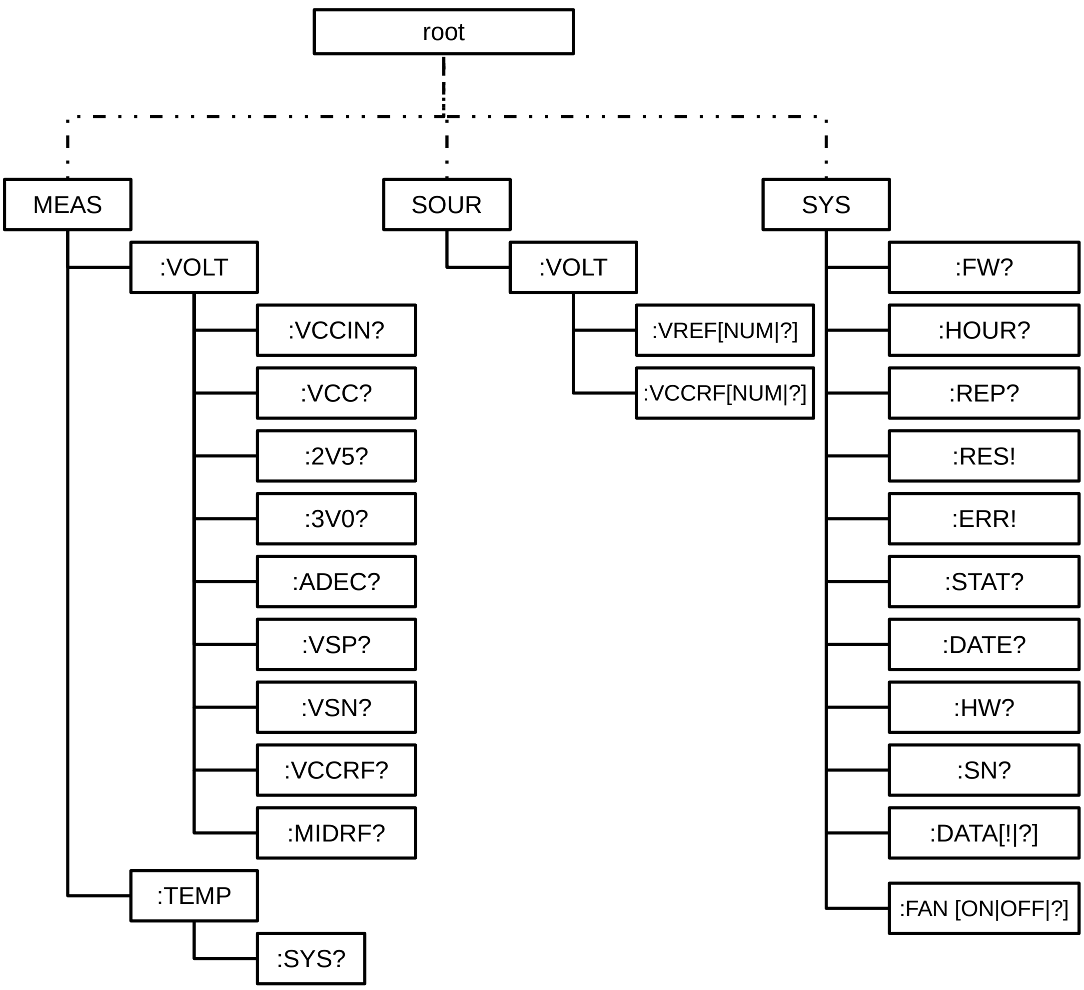

Fig. 11: UART Command Tree

6.2. Command Reference

- **SYS**tem
  - **:FW?**
    - Print firmware version
  - **:HOUR?**
    - Print total uptime
  - **:REP**ort**?**
    - print report
  - **:RES!**
    - Reset System
    - system restarts with stored values
  - **:ERR**or**!**
    - Change to error state
  - **:STAT**us**?**
    - Print current state
  - **:DATE?**
    - Print production date
  - **:HW?**
    - Print hardware revision
  - **:SN?**
    - Print serial number
  - **:DATA!**
    - Switch to data mode
  - **:DATA?**
    - Print active waveform without CRC checksum
  - **:FAN** [ON | OFF]
    - switch FAN on or off
    - after restart fan is always on and should be always on
- **MEAS**ure
  - **:VOLT**age
    - **:VCC**in**?**
      - Voltage external power supply in mV
    - **:VCC?**
      - Internal power supply
    - **:2V5?**
      - Internal power supply 2.5 V
    - **:3V0?**
      - Internal power supply 3.0 V
    - **:ADEC?**
      - Internal power supply for address decoder
    - **:VSP?**

            - Internal positive power supply for internal amplifier
        - **:VSN?**
            - Internal negative power supply for internal amplifier
        - **:VCCRF?**
            - Supply voltage for RF power amplifier
        - **:MIDRF?**
            - Raw supply voltage for RF power amplifier
    - **:TEMP**erature
        - **:SYS?**
            - Internal system temperature in m°C
- **SOUR**ce
    - **:VOLT**age
        - **:VREF?**
            - Print stored DAC reference voltage.
        - **:VREF** <num>
            - set DAC reference voltage in mV (max. 2 V)
        - **:VCCRF?**
            - Print stored supply voltage for RF power amplifier
        - **:VCCRF** <num>
            - set supply voltage for RF power amplifier in mV (12..24 V).

6.3. Command Examples

- MEAS:VOLT:VCCIN?
    - Print measured voltage from external power supply
- SOUR:VOLT:VCCRF 12000!
    - set supply voltage for RF power amplifier,
    - in this example the max. possible output voltage is 6 V at 50 Ω
    - system response: *ACK*

7. Tips and tricks

7.1. Quick start guide

1. For controlling the PPG 512 with your PC, we have to determine the COM-Port
   - first open the device manager by hitting *Windows-Key + R*
   - type *devmgmt.msc* and click OK

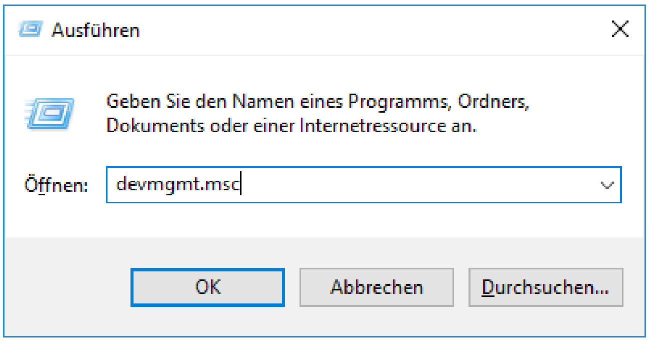

Fig. 13: Run – Device Manager

   - in the device manager find the line *Ports (COM & LPT)* and expand this line
   - connect the PPG 512 with your PC

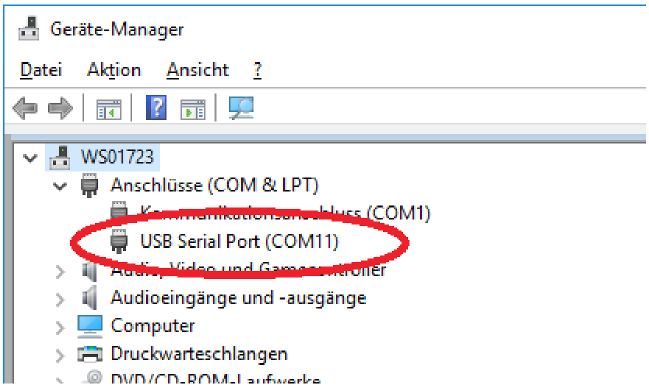

Fig. 14: Device Manager showing connected PPG 512 at Port 11

   - a new COM-Port should appear. The number is arbitrary and is enumerate by the operating system. However, on reconnect Windows should assign the same number to the same device.
   - Windows installs the necessary driver automatically[1]
2. Start your favorite terminal program e. g. *PuTTY*[2] or *TeraTerm*
   - set the correct settings for the UART connection (115200 - 8N1)
   - for setting up PuTTY see Fig. 15
   - click Open and an empty terminal screen should appear

1 When Windows doesn't find the driver, download the correct driver according to your operating system from https://www.ftdichip.com/Drivers/VCP.htm

2 https://www.putty.org/

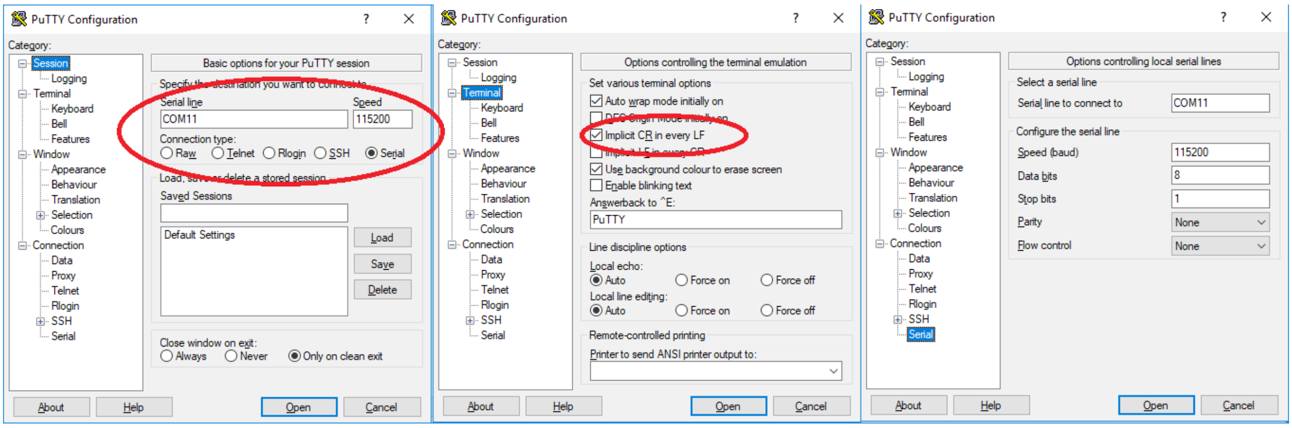

Fig. 15: PuTTY - settings

3. Plug in the external power supply
   - PPG 512 starts with a build in test, while testing the status LED blinks orange
   - after test is finished the LED flashes 3 times green

7.2. Calculating CRC

For generating the CRC checksum use the following python script. The script loads all data from *filename*. The file should only contain one row each value have to be separated by a ‘;’. The CRC calculation is performed by the PyCRC module[1].

With the example waveform.csv (see below) the script should return a **0xB326.**

crc.py:

```
import csv
from PyCRC.CRCCCITT import CRCCCITT

# CRC-CCITT
# polynom: 0x1021
# seed: 0xFFFF

filename='waveform.csv'
f = open(filename)
data = csv.reader(f, delimiter=';')

amplitude = bytearray()

for row in data:
  for column in row:
    amplitude.append(int(column,16))
    # because crc is handled bytewise in PPx 512 a zero padding byte is needed
    amplitude.append(0)

f.close()
hex(CRCCCITT(version="FFFF").calculate(bytes(amplitude)))
```

1For more information about PyCRC see: https://pypi.org/project/PyCRC/

waveform.csv:

0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x
23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23
;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0
x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x2
3;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;
0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x
23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23
;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0
x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x2
3;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;
0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x
23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23
;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0
x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x2
3;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;
0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x
23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23
;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0
x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x2
3;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;
0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23;0x23

7.3. Dynamic range

In order to adjust *VREF* and *VCCRF* a full scale sawtooth signal can be used to determine the upper and lower border for signal generation. When VREF is set to its maximum the amplifier stage can saturate so that using a higher bin value have no effect.

7.4. RF Main Output Attenuation

A lot of oscilloscopes are limited in input voltage and to not blow up the input frontend of the scope external attenuators are used. To achieve fast and narrow pulses an attenuator with high bandwidth should be used.

8. Technical Data / Specifications

Mainframe

Power Input Voltage............................	12 V (max. 18 V)
Current...	max. 2.0 A
External Power supply.........................	100 to 240 VAC, 50/60 Hz, max 100 Watt
Connector type...................................	LEMO EXG0B302HLN-A
Dimensions...	210 x 118 x 57 mm (W x D x H)
Net weight module..............................	0.8 kg
Total weight incl. power supply, etc.….	1.6 kg
Power Dissipation...............................	max. 20 W
Operating Temperature.......................	15 to 25 °C

Pulse Pattern

Length..	512 bytes
Readout speed...................................	5 GS / s; 200 ps time bins;
....	other sampling rates < 5 GS / s on request

RF MAIN Output

Max. Amplitude...................................	6..12 V
Impedance..	50 Ohm
Connector type...................................	SMA (female)

RF AUX Output

Max. Amplitude...................................	~1.5 V
Impedance..	50 Ohm
Connector type...................................	SMA (female)

Synchronization Output

Amplitude..	+500 mV
....	falling edge at byte 253; rising edge at byte 508
Impedance..	50 Ohm
Connector type...................................	SMA (female)

Reset Input

Amplitude..	2.5..5 V
Impedance..	50 Ohm
Connector type...................................	SMA (female)

OP Mode Input

Amplitude..	> 0.75 and < 1.1 V continues pattern generation with byte 0 after reading all 511 bytes
....	< 0.2 V: pattern generation stops after reading 508 bytes
....	unconnected: free-running mode
Impedance..	500 Ohm
Connector type...................................	SMA (female)

USB 2.0 UART (Virtual COM-Port)

Connector type	USB Type-C
Baud rate	115200
Data	8 bit
Parity	none
Stop	1 bit

Retraction of Old Devices

Waste electrical products must not be disposed of with household waste. This equipment should be taken to your local recycling center for safe treatment.
WEEE–Reg.–No. DE 96457402

8.1. Dimensions of the PPG 512 module:

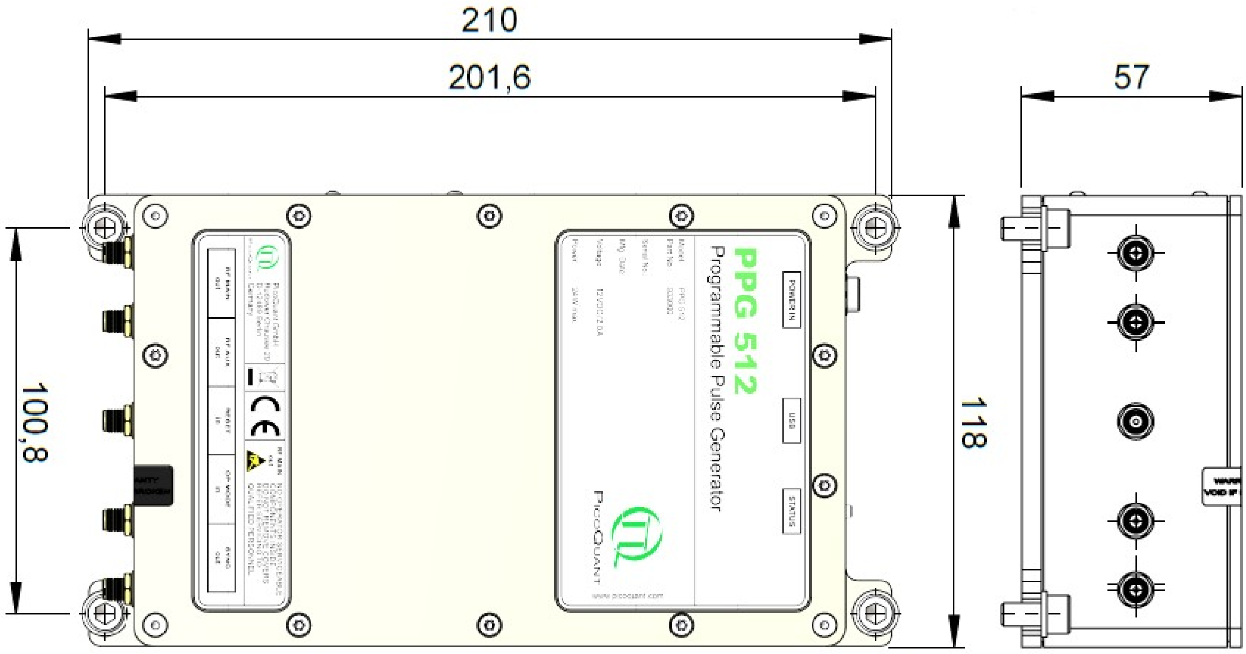

Fig 8.1: Dimensions of the module. Note that all values are given in mm.

9. Support

9.1. Returning Products for Repair

Should you encounter problems that require sending the device in for inspection / repair, please contact us first at: https://support.picoquant.com or support@picoquant.com and request an RMA number before shipping the device. Please include the serial number of your device. Observe precautions against static discharge under all circumstances during handling, packaging and shipping. Use original or equally protective packaging material. Inappropriate packaging voids any warranty.

10. Legal Terms

10.1. Copyright

10.2. Trademarks

11. Further Reading

11.1. PicoQuant Bibliography

PicoQuant maintains a database of publications mentioning PicoQuant devices. It can be found at our website https://www.picoquant.com/scientific/references. It is a valuable source if you would like to know which laboratories are using PicoQuant products or how broad the field of various applications is.

11.2. Download of Technical Notes / Application Notes

PicoQuant, along with our customers, continuously writes and publishes short documents about techniques, methods and applications that are possible with our hardware or software. The download section can be found at https://www.picoquant.com/scientific/technical-and-application-notes

12. Appendix

12.1. Abbreviations

AWG	arbitrary waveform generator
BNC	British Naval Connector or Bayonet Nut Connector or Bayonet Neill Concelman
BIST	Build In System Test
CAMAC	Corporations and Markets Advisory Committee
CRC	cyclic redundancy check
DAC	Digital to analog converter
EMC	Electromanetic compatibility
FWHM	Full Width at Half Maximum
IEC	International Electrotechnical Commission
IR	Infra-red
IRF	Instrument Response Function
LED	Light Emitting Diode
MOFA	Master Oscillator Fiber Amplifier
NIM	Nuclear Instrumentation Methods
OEM	Original Equipment Manufacturer
PM	Polarization Maintaining
RMA	Return Merchandise Authorization
SMA	Sub-Miniature version A (connector type)
STED	STimulated Emission Depletion
TCSPC	Time-Correlated Single Photon Counting
TTL	Transistor-Transistor Logic
UART	Universal Asynchronous Receiver Transmitter
UV	Ultra-violet
VIS	Visible
WEEE	Waste Electrical and Electronic Equipment

PicoQuant GmbH
Rudower Chaussee 29 (IGZ)
12489 Berlin
Germany

P +49-(0)30-1208820-0
F +49-(0)30-1208820-90
info@picoquant.com
www.picoquant.com