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CWCT & BCM-CW-E
CW Current Transformer
Beam Current Monitor for CW beams and Macropulses

User's Manual

Rev. 1.5

Record of updates

Version	Date	Updates performed
1.0	04/2018	First release
1.1	12/2019	Modification of the cover page and creation of the distributors' page
1.2	01/2020	Additions and corrections in the section USB communication
1.3	01/2020	Corrections concerning BCM-CW-E and firmware revisions
1.4	10/2020	Update of CWCT Test Kit 1, GUI and General Specifications; plus minor corrections
1.5.	03/2021	Improved description of USB communication

DISTRIBUTORS

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TABLE OF CONTENTS

INITIAL INSPECTION.....	2
WARRANTY	2
ASSISTANCE	2
SERVICE PROCEDURE.....	2
RETURN PROCEDURE.....	3
SAFETY INSTRUCTIONS.....	3
CWCT & BCM-CW-E SET	4
GENERAL DESCRIPTION.....	5
In-flange models	6
MECHANICAL DIMENSIONS AND DRAWINGS	7
QUICK CHECK	8
Current Transformer Test Fixture.....	8
BCM-CW-E front panel description	10
BCM-RFC rear panel description	11
BCM-CW-E + CWCT Current Measurement Example Setup	12
Setup	13
GRAPHICAL USER INTERFACE	17
Installation	17
BCM-CW-E communication.....	18
GUI user's guide	19
BCM-CW-E FIRMWARE	21
USB COMMUNICATION WITH THE BCM-CW-E.....	21
BCM-CW-E INPUTS / OUTPUTS.....	26
ARCHITECTURE.....	27
GENERAL SPECIFICATIONS.....	28
Measured ranges	31
BCM-CW-E specifications.....	31
Input signals, output signals and other interfaces.....	32
Connectors and pin allocation	33
RECOMMENDATIONS ABOUT CABLES AND INSTALLATION	34
ACCESSORIES.....	35
BCM Chassis: ref. BCM-RFC/xx.....	35
SCHEMATICS & BOARD LAYOUT	36

INITIAL INSPECTION

It is recommended that the shipment be inspected immediately upon delivery. If it is damaged in any way, contact Bergoz Instrumentation or your local distributor. The content of the shipment should be compared to the items listed on the invoice. Any discrepancy should be notified to Bergoz Instrumentation or its local distributor immediately. Unless promptly notified, Bergoz Instrumentation will not be responsible for such discrepancies.

WARRANTY

Bergoz Instrumentation warrants its beam current monitors to operate within specifications under normal use for a period of 12 months from the date of shipment. Spares, repairs and replacement parts are warranted for 90 days. Products not manufactured by Bergoz Instrumentation are covered solely by the warranty of the original manufacturer. In exercising this warranty, Bergoz Instrumentation will repair, or at its option, replace any product returned to Bergoz Instrumentation or its local distributor within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and that the defect has not been caused by misuse, neglect, accident or abnormal conditions or operations. Damages caused by ionizing radiations are specifically excluded from the warranty. Bergoz Instrumentation and its local distributors shall not be responsible for any consequential, incidental or special damages.

ASSISTANCE

Assistance in installation, use or calibration of Bergoz Instrumentation beam current monitors is available from Bergoz Instrumentation, 01630 Saint Genis Pouilly, France. It is recommended to send a detailed description of the problem by email to info@bergoz.com.

SERVICE PROCEDURE

Products requiring maintenance should be returned to Bergoz Instrumentation or its local distributor. Bergoz Instrumentation will repair or replace any product under warranty at no charge. The purchaser is only responsible for transportation charges.

For products in need of repair after the warranty period, the customer must provide a purchase order before repairs can be initiated. Bergoz Instrumentation can issue fixed price quotations for most repairs. However, depending on the damage, it may be necessary to return the equipment to Bergoz Instrumentation to assess the cost of repair.

RETURN PROCEDURE

All products returned for repair should include a detailed description of the defect or failure, name, phone number and email of the user. Contact Bergoz Instrumentation or your local distributor to determine where to return the product. Returns must be notified by email prior to shipment.

Return should be made prepaid. Bergoz Instrumentation will not accept freight-collect shipment. Shipment should be made via UPS, FedEx or DHL. Within Europe, the transportation service offered by the Post Offices "EMS" (Chronopost, Datapost, etc.) can be used. The delivery charges or customs clearance charges arising from the use of other carriers will be charged to the customer.

SAFETY INSTRUCTIONS

This instrument is operated from the mains power supply. For safe operation, it must be grounded by way of the grounding conductor in the power cord. Use only the fuse specified. Do not remove cover panels while the instrument is powered. Do not operate the instrument without the cover panels properly installed.

Chassis originally shipped to U.S. or Canada feature AC mains power entry modules where the Phase is fused and the Neutral unfused, as is the rule.

Chassis to other destinations but U.S. and Canada feature AC mains power entry modules where both Phase and Neutral are fused.

When a chassis with unfused Neutral is used outside the U.S. and Canada, both Phase and Neutral should be fused:

The Power entry module must be opened, the Phase fuse must be removed, the fuse holder must be flipped; its reverse side presents two slots where two new fuses must be inserted, one in each slot.

The fuses rating must be same as the Phase fuse that was removed.

The Toroid sensor contains materials such as cobalt and iron. Those materials may become radioactive when exposed to high energy particle beams. Follow applicable radiation-safety procedures when the Toroid sensor must be moved out of controlled areas.

CWCT & BCM-CW-E SET

This manual applies to BCM-CW-E revisions 222.1 with firmware 1.4 and above. It does NOT apply to earlier BCM-CW-E revisions or earlier firmware versions. It does not apply to either BCM-IHR-E, BCM-CA-E or BCM-RF-E.

The CWCT & BCM-CW-E set includes:

- CWCT Current Transformer
- BCM-CW-E electronics module
- BCM-RFC/xx 19" RF-shielded chassis for BCM-E modules of all versions with power supply and spare power supply
- BCM-Cxx CWCT to BCM-RFC chassis interconnect standard coaxial cable in PEX dielectric with PTFE connectors
- Option: BCM-RHC/xx CWCT to BCM-RFC chassis interconnect coaxial cable in PEX dielectric with PEEK connectors.



In-flange CWCT and BCM-CW-E

BCM-RFC/xx RF shielded chassis is compatible with BCM-CW-E, BCM-IHR-E and BCM-RF-E. BCM-CW-E, BCM-IHR-E and BCM-RF-E electronics modules can be mixed in the same BCM-RFC/xx chassis.

Power supply must however be dimensioned according to power consumption. Please contact Bergoz Instrumentation before adding more BCM modules into a chassis.

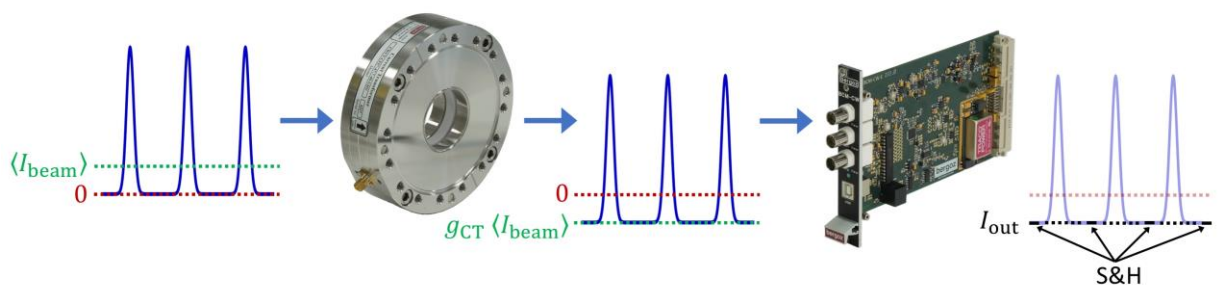
GENERAL DESCRIPTION

CWCT and BCM-CW-E is designed to measure average current of CW beam and macropulses.

The CWCT is a current transformer with strict limits on lower and upper cut-off frequencies, tailored to the beam properties. Its lower cut-off assures that droop between bunches is negligible, yet high enough to allow full differentiation of its output signal as quickly as possible. Its upper cut-off is high enough to allow its output signal return to baseline after each bunch.

The BCM-CW-E is the electronics module processing the CWCT output signal. It provides an output voltage proportional to the beam average current.

The BCM-CW-E contains a fast sample-and-hold circuit which measures the CWCT signal in between two consecutive pulses. This baseline signal is proportional to the average beam current passing through the CWCT. Additional filters remove high and low frequency noise. A low-noise input amplifier can be used to increase sensitivity.



The BCM-CW-E electronics module includes:

- Gain control of the RF signal input amplification: 0dB, +20dB, +40dB, and RF Signal input disconnect. This function can be controlled by either logic levels (see rear panel DB9 description) or via USB.
- Timing adjustment of baseline measurement: Timing adjustment is necessary to sample the baseline at the right time. A programmable delay line is available onboard, allowing a timing delay up to 10ns in 10ps steps. This delay line can be controlled via USB only. When USB control is not available, the sample time must be adjusted by delaying the “Trigger in” signal.

The BCM-CW-E embeds a PIC microcontroller that can be used for BCM-CW-E configuration and digital data read-out. The digital data read-out is not calibrated. It should not be used for high precision measurements.

The communication is done via specific USB commands, e.g. as used by the BCM-CW-E graphical user interface (GUI). Details on the GUI and USB communication are described later in this manual.

WARNING: PIC configuration

At the time of delivery, BCM-CW-E is in the "Ex-factory" configuration.

Do not change those settings until you are familiar with the BCM-CW system.

In-flange models

In-flange models are current transformers whose cores are embedded in a pair of flanges. Flanges can be Conflat, ISO, KF, Dependex, EVAC or specials with usual inner diameters. In-flange models are UHV compatible down to 1e-9 mbar. Soap or alcohol cleaning before installation is however recommended. To reach pressure down to 1e-11 mbar, adequate pumping and cleaning, e.g. plasma, are required.

100°C (212°F) should never be exceeded at any time during bake out or operation unless the CWCT is made from a selection of higher temperature alloys and materials:

- Option BK150C allows bake out at 150°C (300°F)
- Option BK185C allows bake out at 185°C (365°F)
- Option BK200C allows bake out at 200°C (392°F)

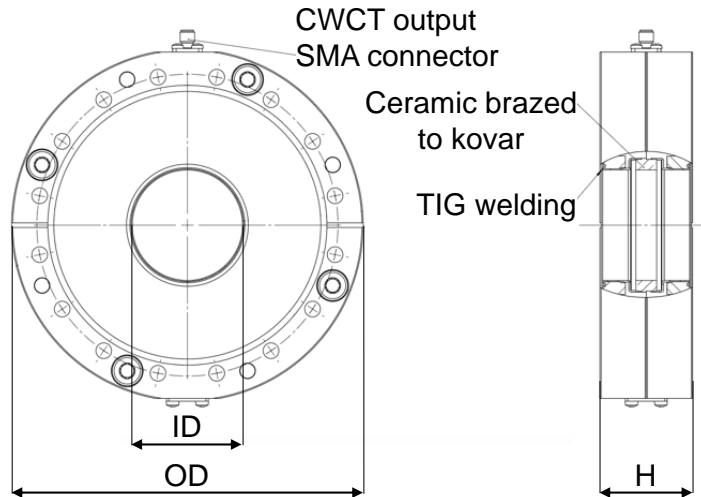
CWCT wall current break ("gap") is a ceramic ring (Al2O3 99.7%) brazed onto two Kovar transition sleeves.

Standard models are made from AISI 304 steel, AISI 316LN is available on option.

CWCT part number has the below syntax:

CWCT	
-CFx"-	x" is the CF flanges OD [inch]
-xx.x-	xx.x is the sensor ID [mm]
-xx-	xx is the sensor axial length [mm]
-UHV-	UHV: Sensor UHV compatible with brazed ceramic wall current break; As delivered down to 1e-9 mbar After adequate cleaning down to 1e-11 mbar
Example: CWCT-CF6"-60.4-40-UHV	
Options for In-flange CWCT	
-ARBxx-	In-flange CWCT sensor with special arbitrary aperture
-2CORE-	Two cores instead of one core, doubles sensitivity
-RFBYP-	RF-bypass over ceramic
-316LN-	In-flange CWCT sensor in AISI316LN instead of 304
-BK150C-	In-flange CWCT sensor bakeable at 150°C (300°F)
-BK185C-	In-flange CWCT sensor bakeable at 185°C (365°F)
-BK200C-	In-flange CWCT sensor bakeable at 200°C (392°F)
-H	Radiation-tolerant sensor option, all components R.I.>6

MECHANICAL DIMENSIONS AND DRAWINGS



In-flange CWCT sensor order code	Flange OD (inch)	Pipe OD (inch)	Mating flange	CWCT ID (mm)	CWCT H (mm)
CWCT-CF3"3/8-22.2-40-UHV-xx	3.375"	1"	DN/NW50CF	22.2	
CWCT-CF4"1/2-34.9-40-UHV-xx	4.5"	1.5"	DN/NW63CF	34.9	
CWCT-CF4"1/2-38.0-40-UHV-xx	4.5"	40 mm	DN/NW63CF	38.0	
CWCT-CF6"-47.7-40-UHV-xx	6"	2"	DN/NW100CF	47.7	
CWCT-CF6"-60.4-40-UHV-xx	6"	2.5"	DN/NW100CF	60.4	
CWCT-CF6"3/4-96.0-40-UHV-xx or CWCT-CF8"-96.0-40-UHV-xx	6.75" 8"	4"	DN/NW130CF DN160/NW150CF	96.0	
CWCT-CF10"-147.6-40-UHV-xx	10"	6"	DN/NW200CF	147.6	
CWCT-CF12"-198.4-40-UHV-xx	12"	8"	DN/NW250CF	198.4	
CWCT-CFXX"-XXX-XX-UHV-10.0 V/A and lower					40.0

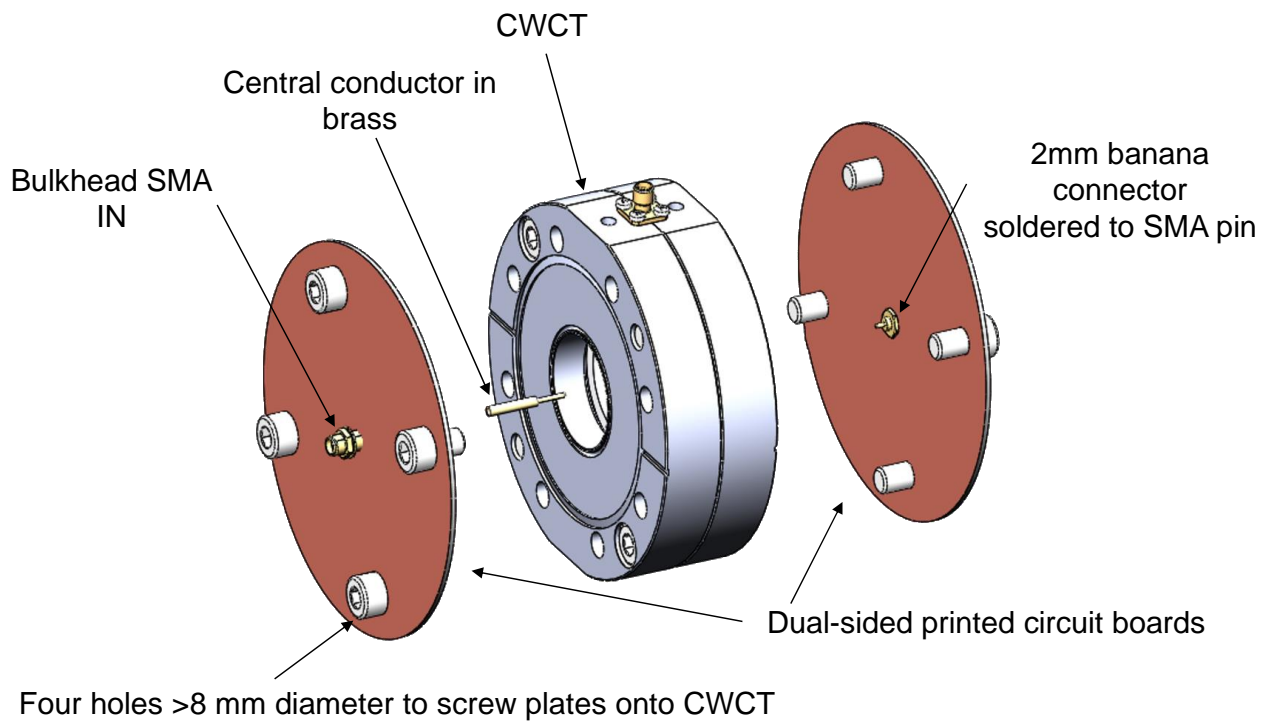
QUICK CHECK

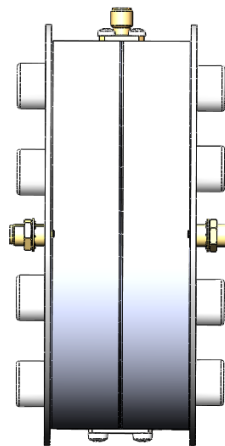
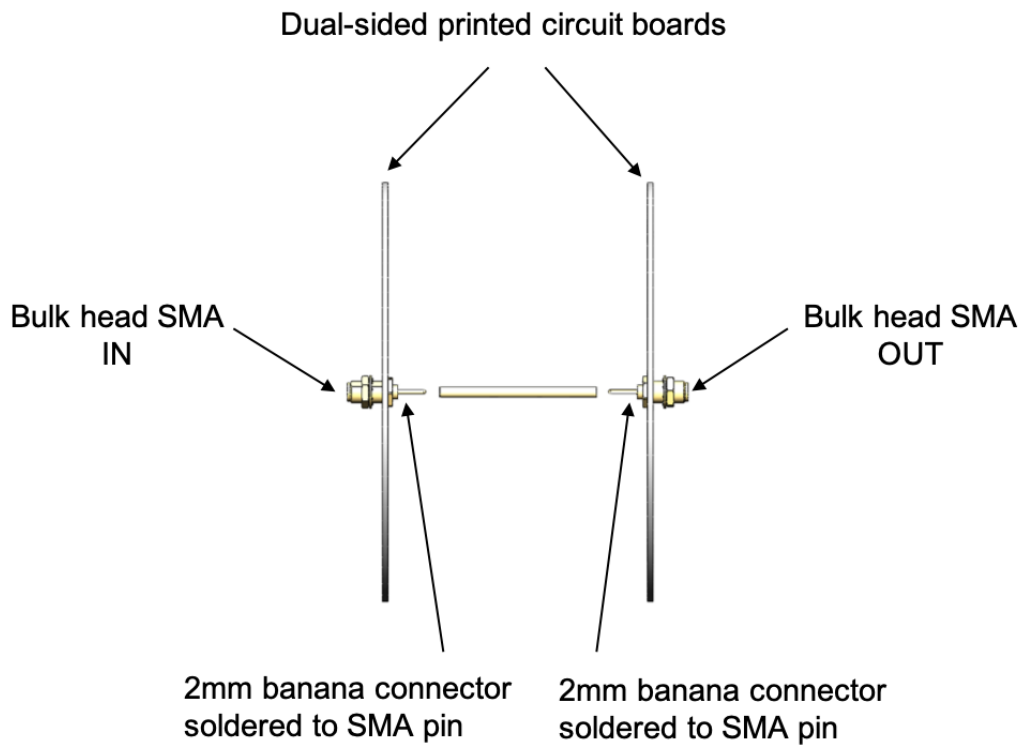
Before installation in the accelerator, different bench tests can be performed to get familiar with the CWCT and the BCM-CW-E.

Current Transformer Test Fixture

Measurements can be performed in a workshop using an RF signal generator, square wave generator or CW pulse generator, as described below in quick check setups 1 and 2. A test fixture is required to transmit the signal through the CWCT aperture. This test fixture is described here.

CWCT test fixture:





BCM-CW-E front panel description



Signal View:

CWCT Signal, after input amplification (50 Ω readout).

Output View:

Baseline output voltage proportional to the average input current (1 M Ω readout).

Timing View:

When displayed together with "Signal View", shows triggering point reference (positive edge zero crossing) of baseline measurement reference (tunable via USB) (50 Ω readout)¹.

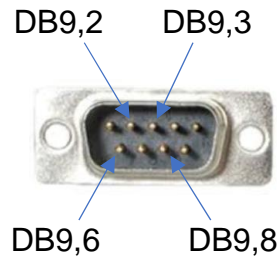
Power ON LED

USB connector type B:

Data readout and remote control.

¹ To ensure a perfect coincidence between Signal View and Timing View, you should use coax cables of equal length and equal characteristics. Otherwise a phase adjustment may be needed on your oscilloscope, to correct for cable- or oscilloscope-induced timing errors.

BCM-RFC rear panel description



Remote control:

Pin DB9,6: Input TTL Gain Control A (internal Pull up to 5V) (see Hardware Gain Control Input table below)

Pin DB9,2: Input TTL Gain Control B (internal Pull up to 5V) (see Hardware Gain Control Input table below)

Pin DB9,8: Baseline output – 10 kHz bandwidth
 Output voltage proportional to the average beam current (1 M Ω readout).

Pin DB9,3: Baseline output – 100 Hz bandwidth
 Output voltage proportional to the average beam current (1 M Ω readout).

Pins DB9,1; DB9,4; DB9,5; DB9,7; DB9,9: connected to GND

BCM Input:

BCM-CW-E input signal from the CWCT.

BCM Output:

Full bandwidth baseline output voltage proportional to the average beam current (50 Ω readout). This signal follows beam current fluctuations within 1 μ s, permitting fast detection of beam loss.

Trigger in:

Synchronized to Beam RF

See General Specifications chapter on page 29 for trigger properties

Hardware Gain Control Input (DB9)		
DB9,6	DB9,2	Input Gain
OPEN (High)	OPEN (High)	ISOLATED
GROUNDDED (Low)	OPEN (High)	Gain: 0dB
OPEN (High)	GROUNDDED (Low)	Gain: 20dB
GROUNDDED (Low)	GROUNDDED (Low)	Gain: 40dB

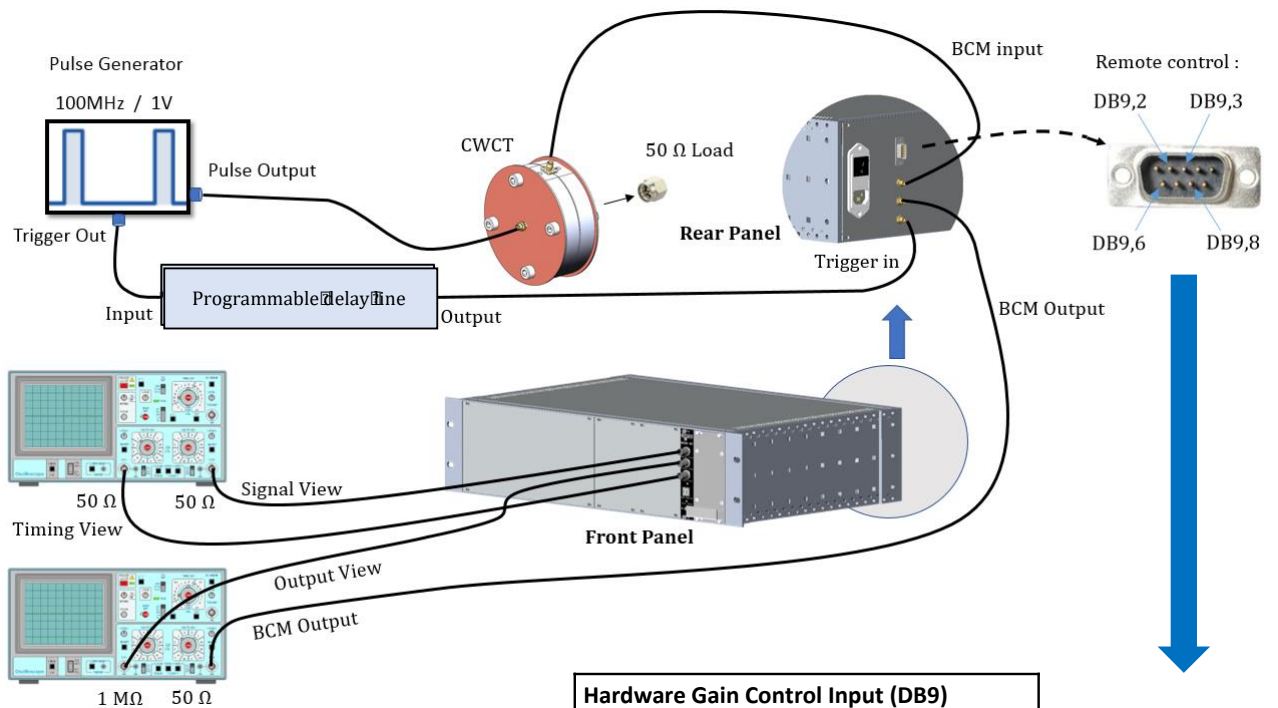
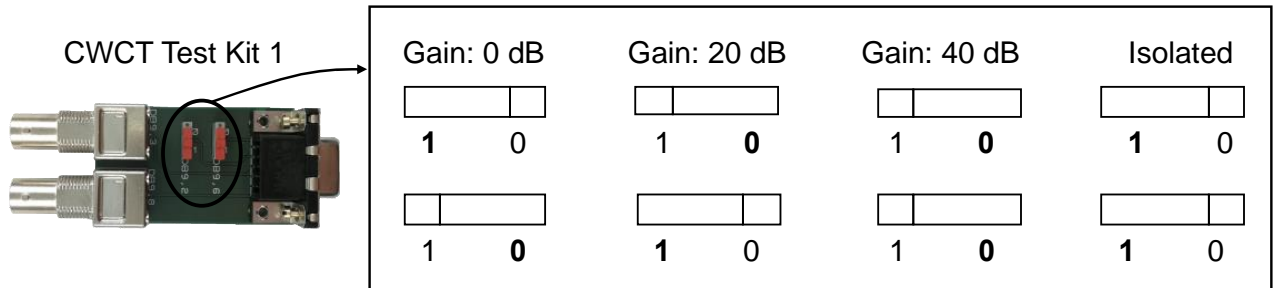
BCM-CW-E + CWCT Current Measurement Example Setup

What is needed:

- CWCT
- Current Transformer test fixture (see description page 8)
- BCM-CW-E electronics module
- BCM-RFC/xx chassis
- RF Pulse generator, 15MHz minimum, with a 50% Duty cycle trigger output
- Programmable delay line allowing delay adjustment up to 60ns in 50ps steps preferably
- A single four-channel oscilloscope or two dual-channel oscilloscopes with 500 MHz bandwidth or higher
- SMA 50 Ω load
- Short (1–2 m) 50 Ω coaxial cables
- SMA/BNC adapters.

Setup

Default State
 Ex-factory default state: Gain Control thru "Remote control" DB9.



Hardware Gain Control Input (DB9)		Input Gain
DB9,6	DB9,2	
OPEN (High)	OPEN (High)	ISOLATED
GROUND (Low)	OPEN (High)	Gain: 0dB
OPEN (High)	GROUND (Low)	Gain: 20dB
GROUND (Low)	GROUND (Low)	Gain: 40dB

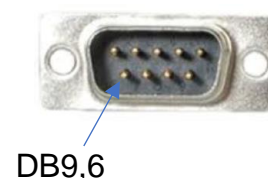
BCM-CW-E which have been controlled by USB may be left in a state other than Ex-factory default state. E.g., control via DB9 may be disabled

- 1) At time of shipment, the AC mains voltage is set according to the country of destination. A label on the power supply unit shows the AC voltage it is set up to. Check that it corresponds to your AC mains voltage. Turn OFF the chassis power switch and connect the AC mains to the chassis.
- 2) Adjust the Pulse Generator: e.g. 100MHz / 1Vp-p / duty cycle: 20% to 50%
- 3) CWCT must be mounted in the test fixture.
- 4) Connect the Pulse generator output to the CWCT test fixture SMA input.
- 5) Connect CWCT test fixture SMA output to a 50Ω Load.
- 6) Connect CWCT output to the “BCM input” SMA located on the chassis rear panel.
- 7) Connect Trigger Output from Pulse generator to the Programmable delay line.
- 8) If Trigger signal from Programmable Delay Line exceeds 200mVp-p, insert attenuators till signal is in range 20mVp-p ... 200mVp-p
- 9) Connect Output from Programmable delay line to “Trigger Input” located on the chassis rear.
- 10) Connect “Output View” located on front panel to a 1 MΩ oscilloscope.
- 11) Connect “BCM Output” SMA located on the chassis rear panel to an 50Ω oscilloscope.
- 12) Connect “Signal View” BNC located on front panel to a 50 Ω oscilloscope.
- 13) Connect “Timing View” BNC located on front panel to a 50 Ω oscilloscope.
- 14) Turn ON the BCM-RFC/xx chassis power switch.
- 15) Select an appropriate input Gain using DB9 Remote control Pins (DB9,6 & DB9,2)

Hardware Gain Control Input (DB9)		
DB9,6	DB9,2	Input Gain
OPEN (High)	OPEN (High)	ISOLATED
GROUNDDED (Low)	OPEN (High)	Gain: 0dB
OPEN (High)	GROUNDDED (Low)	Gain: 20dB
GROUNDDED (Low)	GROUNDDED (Low)	Gain: 40dB

e.g. to select a Gain =40dB DB9,2 should be left open (unconnected) and DB9,6 should be connected to ground.

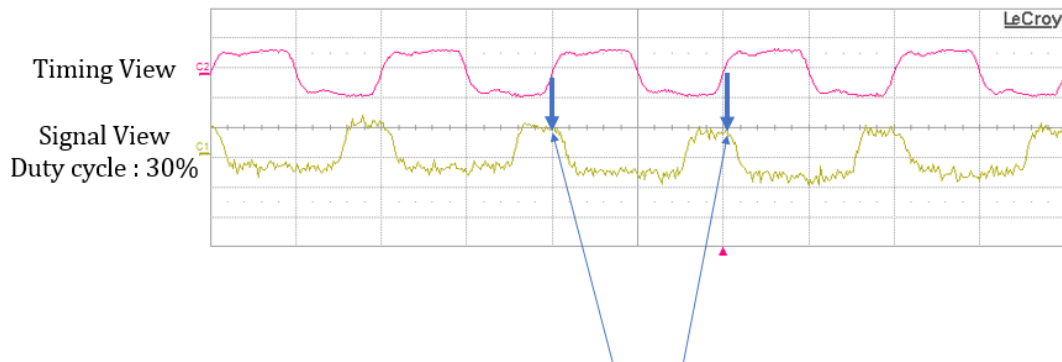
DB9,6 to be connected to any GND Pin:
 DB9,1 DB9,4 DB9,5 DB9,7 DB9,9



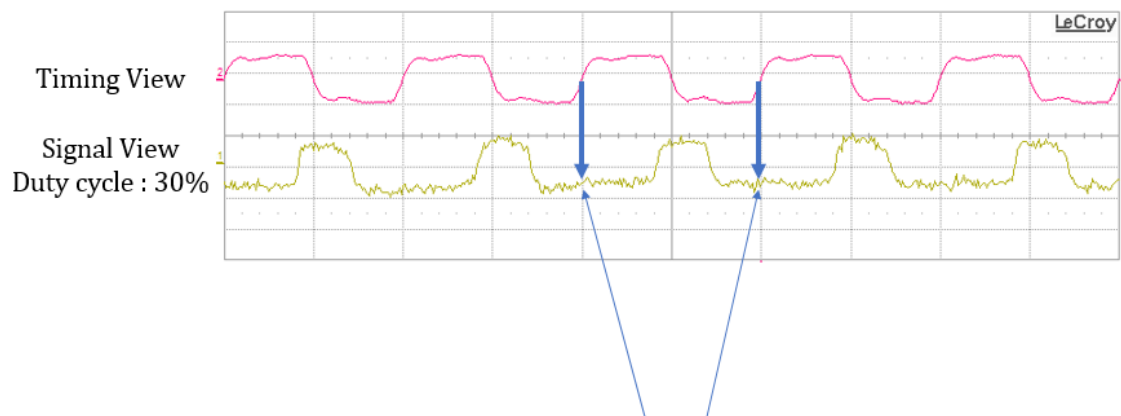
Note: Available DB9 Ground Pins are: DB9,1 DB9,4 DB9,5 DB9,7 DB9,9

16) Turn ON the Pulse Generator

Visualize “Timing View”, “Signal View”, “BCM Output”, and “Output View”;
Adjust the delay line to get a good Baseline measurement.



Wrong Baseline Sampling time



Good Baseline Sampling time

In case “Signal View” is not well visible, select a higher Gain.

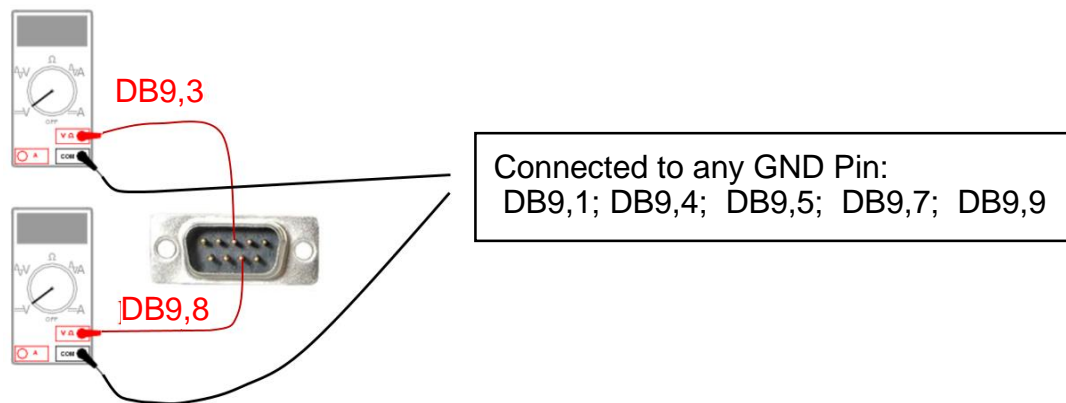
The Baseline voltage is available on the following output ports:

“BCM Output” located on chassis Rear Panel: Full Bandwidth

“Output View” located on BCM-CW-E Front Panel: Full Bandwidth

“DB9,8”: located on chassis Rear Panel: 10 kHz bandwidth

“DB9,3”: located on chassis Rear Panel: 100 Hz bandwidth



All these output voltages are proportional to the average current going through the CWCT.

The transfer functions to get the current from the output voltages are indicated in the calibration report.

The transfer functions depend on:

- BCM Output port
- Input Gain

GRAPHICAL USER INTERFACE

Bergoz Instrumentation provides a GUI to communicate with the BCM-CW-E via USB. It allows to control the BCM-CW-E settings and to acquire the BCM-CW-E output signal.

This software was developed with LabVIEW 2014. It is provided as an executable file. The .vi file can be obtained upon request to info@bergoz.com

Operating systems supported:

Any Microsoft Windows version that can run LabVIEW 2014 or the corresponding run time environment and the NI-VISA driver package, e.g. Windows XP, Vista, 7, 8, 10.

The installer package of the BCM-CW system GUI contains the LabVIEW run time environment and the VISA drivers. They can also be obtained from the National Instruments web site.

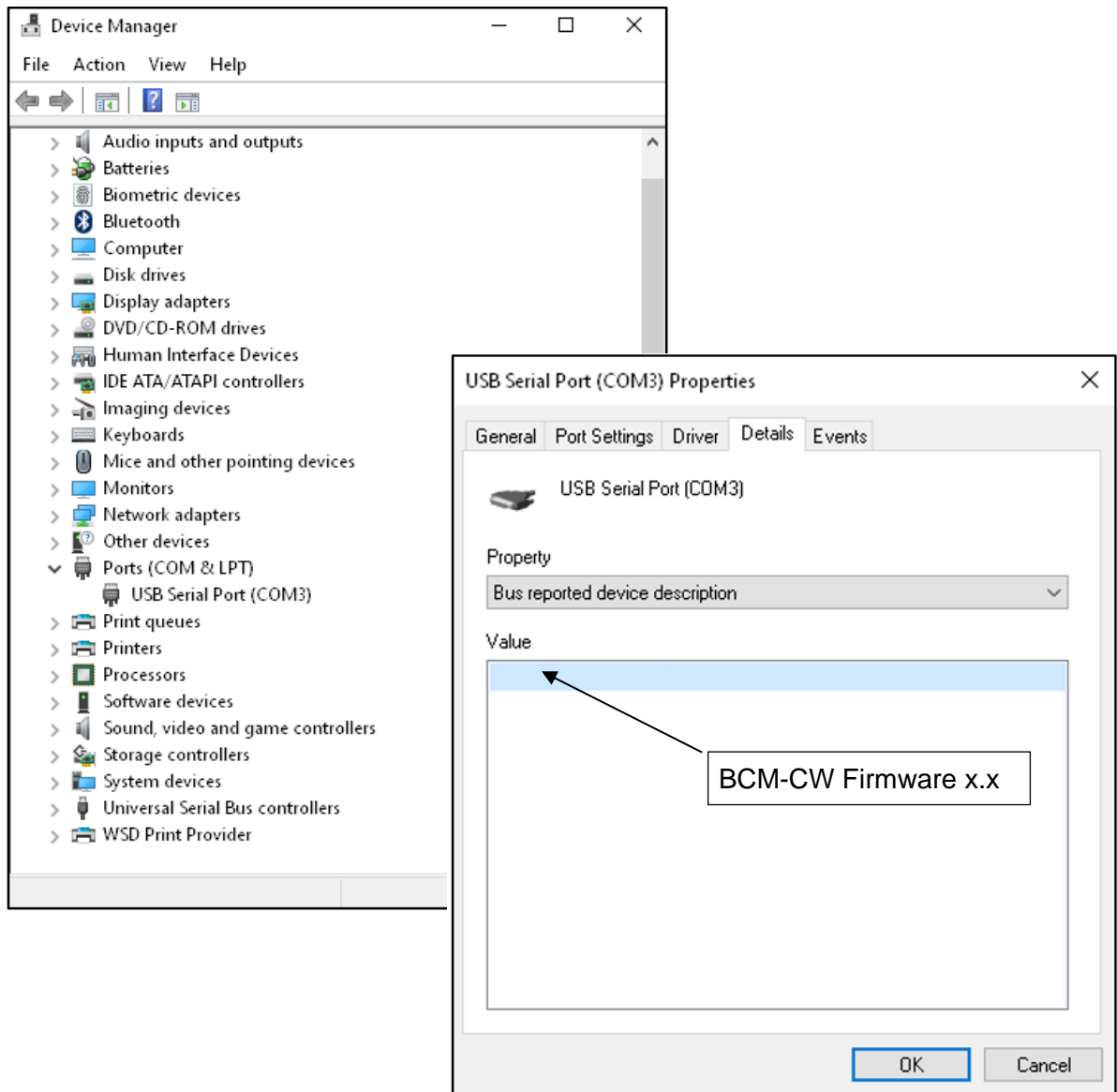
The Microchip USB CDC serial driver might be required on Windows systems to communicate with the BCM-CW-E. This driver is part of the Microchip Libraries for Applications (USB). It is also provided with the BCM-CW-E or can be obtained from Bergoz Instrumentation upon request to info@bergoz.com

Installation

- 1) At time of delivery, a USB stick is attached to the last page of the printed manual accompanying the CWCT / BCM-CW-E. Open the folder containing the BCM-CW GUI Installer.
- 2) Run the Setup executable file and proceed with the installation.
- 3) The BCM-CW GUI application (.exe) is installed at the location specified during installation. If necessary, also the LabVIEW 2014 run-time environment and the NI VISA drivers are installed.
- 4) The Microchip USB CDC serial driver is provided on the USB stick in a compressed ZIP archive. Un-compress this archive. A folder will be created containing the files necessary for driver installation.
- 5) Right-click on the file "mchpcdc.inf" and choose "Install".

BCM-CW-E communication

- 1) Connect the USB cable from the BCM-CW-E front panel USB port to the PC.
- 2) Windows automatically recognizes the device and loads the USB CDC serial driver.
- 3) In the device manager, look for the serial COM port number associated to the BCM-CW-E.



- 4) Enter the COM port in the GUI front panel.
- 5) Run the GUI; communication with BCM-CW-E USB port starts.

GUI user's guide

The graph is displaying the BCM-CW-E output voltage.

The screenshot shows the main GUI window with the following labeled components:

- COM PORT configuration:** Points to the 'COM3' dropdown menu.
- STOP GUI:** Points to the 'STOP' button in the top right.
- SCAN STEP modification:** Points to the 'Scan Step' dropdown menu.
- DELAY CONTROL displayed in picoseconds:** Points to the 'Delay Control (Time Value)' slider.
- DELAY CONTROL displayed in digital step:** Points to the 'Delay Control (Digital Value)' slider.
- DELAY applied in picoseconds:** Points to the 'ps' unit label.
- DELAY applied in digital step:** Points to the 'Steps' unit label.
- BCM-CW-E Serial Number:** Points to the 'Serial Number' field.
- SAVE CONFIGURATION button:** Points to the 'Save Configuration to BCM-CW-E EEPROM' button.
- GAIN selection:** Points to the 'PIC GAIN Control' and 'DB9 GAIN Control' buttons.
- DELAY SCAN Toggle: UP: Activated DOWN: Stopped:** Points to the 'Delay Scan on/off' toggle.
- DB9/PIC SELECT Toggle:** Points to the 'DB9/PIC SELECT Toggle' button.

A red box highlights the 'Transfer Function' and 'Calibration Constants' tabs. A zoomed-in view of these tabs is shown below:

Transfer Function	Calibration Constants												
On/Off <input checked="" type="checkbox"/> Transfer Function beam [mA] = (Ubcm - 0.002560 V) / (1.858340 V/mA)	<table border="1"> <thead> <tr> <th>Gain 0 dB [V/mA]</th> <th>Gain 20 dB [V/mA]</th> <th>Gain 40 dB [V/mA]</th> </tr> </thead> <tbody> <tr> <td>0.020450</td> <td>0.194050</td> <td>1.858340</td> </tr> <tr> <th>Offset 0 dB [V]</th> <th>Offset 20 dB [V]</th> <th>Offset 40 dB [V]</th> </tr> <tr> <td>0.005910</td> <td>0.004750</td> <td>0.002560</td> </tr> </tbody> </table>	Gain 0 dB [V/mA]	Gain 20 dB [V/mA]	Gain 40 dB [V/mA]	0.020450	0.194050	1.858340	Offset 0 dB [V]	Offset 20 dB [V]	Offset 40 dB [V]	0.005910	0.004750	0.002560
Gain 0 dB [V/mA]	Gain 20 dB [V/mA]	Gain 40 dB [V/mA]											
0.020450	0.194050	1.858340											
Offset 0 dB [V]	Offset 20 dB [V]	Offset 40 dB [V]											
0.005910	0.004750	0.002560											

Labels for the zoomed-in view:

- TRANSFER FUNCTION ON/OFF:** Points to the 'On/Off' checkbox.
- CALIBRATION CONSTANTS Modification:** Points to the gain and offset values.

PIC GAIN Control Tab:

- This window is active if DB9 / PIC SELECT toggle is set to "PIC GAIN Control".
- Three BCM input amplification gains can be selected:
 - 0dB
 - 20dB
 - 40dB
 - OFF: BCM input isolated

DB9 GAIN Control Tab:

- This window is active if DB9 / PIC SELECT toggle is set to "DB9 GAIN Control".
- This window shows the gain selected by hardware (DB9).

COM Port configuration:

- Address of the virtual COM port used by the BCM-CW-E for communication.

Delay Control:

- Used to set up the correct timing of the clock signal relative to the beam signal.
Can be set as temporal value (in picoseconds) or as digital value (delay step number).

Delay Scan:

- Toggle on/off the automatic clock delay scan.

Scan Step:

- Temporal step of the automatic delay scan.

Transfer Function Tab:

- Toggle on/off the conversion of measured voltage values to average beam current.

Calibration Constants Tab:

- Calibration constants required to convert measured voltage to average beam current.
Ex-factory set to the calibration constants for the 100Hz output (see calibration report).

Save Configuration to BCM-CW-E:

- Stores the current BCM-CW-E settings in the BCM-CW-E microcontroller EEPROM.
The settings saved to the EEPROM will be restored when the BCM-CW-E is switched on.

BCM-CW-E FIRMWARE

The BCM-CW-E embeds a PIC18F2458 microcontroller from Microchip Technology Inc. This microcontroller includes a 12bit ADC and allows USB communication.

The BCM-CW-E firmware is written in C using the MPLAB 8.9 IDE and the MPLAB C18 compiler, both available from the Microchip website: www.microchip.com.

The firmware code can be obtained from Bergoz Instrumentation upon request. Users can freely modify the code to fit at best their own application.

To program and debug the microcontroller, remove the BCM-CW-E cover shield and connect an ICD3 Microchip In-circuit debugger to the RJ11-R connector (see I/O AND SWITCHES section). BCM-XTD card extender may be required to extend the BCM-CW-E out of its BCM-RFC chassis

USB COMMUNICATION WITH THE BCM-CW-E

Communication between host PC and BCM-CW-E is performed via the microcontroller's built-in USB to serial converter. The connection is done with a USB cable. But for data transmission, the BCM-CW-E appears attached to a serial port of the host.

The Microchip USB CDC serial driver might be required on Windows systems to communicate with the BCM-CW-E USB port. This driver is part of the Microchip Libraries for Applications (USB). It is also provided during delivery of the CWCT / BCM-CW-E or can be obtained from Bergoz Instrumentation upon request.

The BCM-CW-E uses the Communication Devices Class USB protocol in POLLING mode. All data is transmitted as character strings.

A general frame used to send a command from the host to the BCM-CW-E looks like this:

1 char Frame type	1 char Frame number	1 char Write / Read indicator	8 char Value	2 char Termination
'A' to 'Z'	'0' to '9'	':' write data to PIC or '?' demand data from PIC	00000000 to FFFFFFFF HEX value	\n\0 Ascii(10) Ascii(0)

Examples: "D0:00000005\n\0", "D0?\n\0"

If data is demanded from the BCM-CW-E using the read indicator '?', the eight value characters can be omitted.

It is possible to concatenate a few frames in a single line send to the BCM-CW-E. It is sufficient that each frame ends by \0 (ascii(0)) instead of \n\0 (ascii(10) ascii(0)).

Warning!

The BCM-CW-E firmware does not always disregard wrongly formatted frames. It is mandatory that the value send to the BCM-CW-E is exactly eight characters long and contains only hexadecimal numbers. Otherwise the BCM-CW-E might misbehave.

A general frame received by the host from the BCM-CW-E looks like this:

1 char Frame type	1 char Frame number	1 char Separator	4 char Counter	1 char Separator	8 char Value	2 char Termination
'A' to 'Z'	'0' to '9'	':'	0000 to FFFF HEX value	'='	00000000 to FFFFFFFF HEX value	\n0 Ascii(10) Ascii(0)

Example: "D0:0123=00000005\n0"

The analog BCM-CW-E output signal is periodically sampled by the microcontroller's 12bit ADC. The sampled value is then automatically sent to the host via USB.

Frames automatically sent by the BCM-CW-E to the host:

Frame type	Description	Example (omitting termination)
A	BCM-CW-E's ADC sampled voltage in microvolts	A0:0123=00123ABC

Note on HEX value format:

The 4 char counter is an unsigned integer value in HEX format, i.e. its decimal range is 0 to 65535. The 8 char value may be either an unsigned integer value in HEX format, i.e. its decimal range is 0 to 4294967295, or a signed integer value stored as two's complement in HEX format, i.e. its decimal range is -2147483648 to 2147483647.

This table describes the write commands, that can be send by the host to the BCM-CW-E. These commands change the BCM-CW-E configuration. The BCM-CW-E does not return a response:

Command	Description	Command Frame (omitting termination)	Comments
D	Set on-board digital delay line value (steps, 10bit)	D0:00000xxx	"xxx" must be an integer number in HEX format within the range "000" to "3FF", i.e. step 0 to 1023 ²
T	Set on-board digital delay line value (picoseconds)	T0:0000xxxx	"xxxx" must be an integer number in HEX format within the range "0000" to "2374", i.e. approx. 0 to 9076ps ²
E	Save BCM-CW-E configuration to microcontroller EEPROM	E0:00000001	The value should equal "00000001", no other values are defined
G	Set BCM-CW-E Gain Configuration	G0:0000000x	Single bits of the character "x" are used for configuration (bit count ranges from 0 to 7): DB9/PIC Gain control: Bit5 = 0 => set gain control to PIC Bit5 = 1 => set gain control to DB9 The following gain control bits are used if Bit5 = 0 (gain controlled by PIC) Bit6 = 0 and Bit7 = 0 => 40dB gain Bit6 = 1 and Bit7 = 0 => 20dB gain Bit6 = 0 and Bit7 = 1 => 0dB gain Bit6 = 1 and Bit7 = 1 => input switched off
I	Set transfer function on/off state	I0:00000001 I0:00000000	on off
C	Set calibration constants	C0:xxxxxxxx C1:xxxxxxxx C2:xxxxxxxx C3:xxxxxxxx C4:xxxxxxxx C5:xxxxxxxx	"xxxxxxxx" must be an integer number in HEX format within the range "00000000" to "FFFFFFFF". C0 and C1 are transfer function gain and offset in "0dB gain" mode. C2 and C3 are transfer function gain and offset in "20dB gain" mode. C4 and C5 are transfer function gain and offset in "40dB gain" mode.

² More details on delay in ANNEX I

This table describes the read commands that can be send by the host to the BCM-CW-E and the corresponding response frames returned by the BCM-CW-E back to the host.

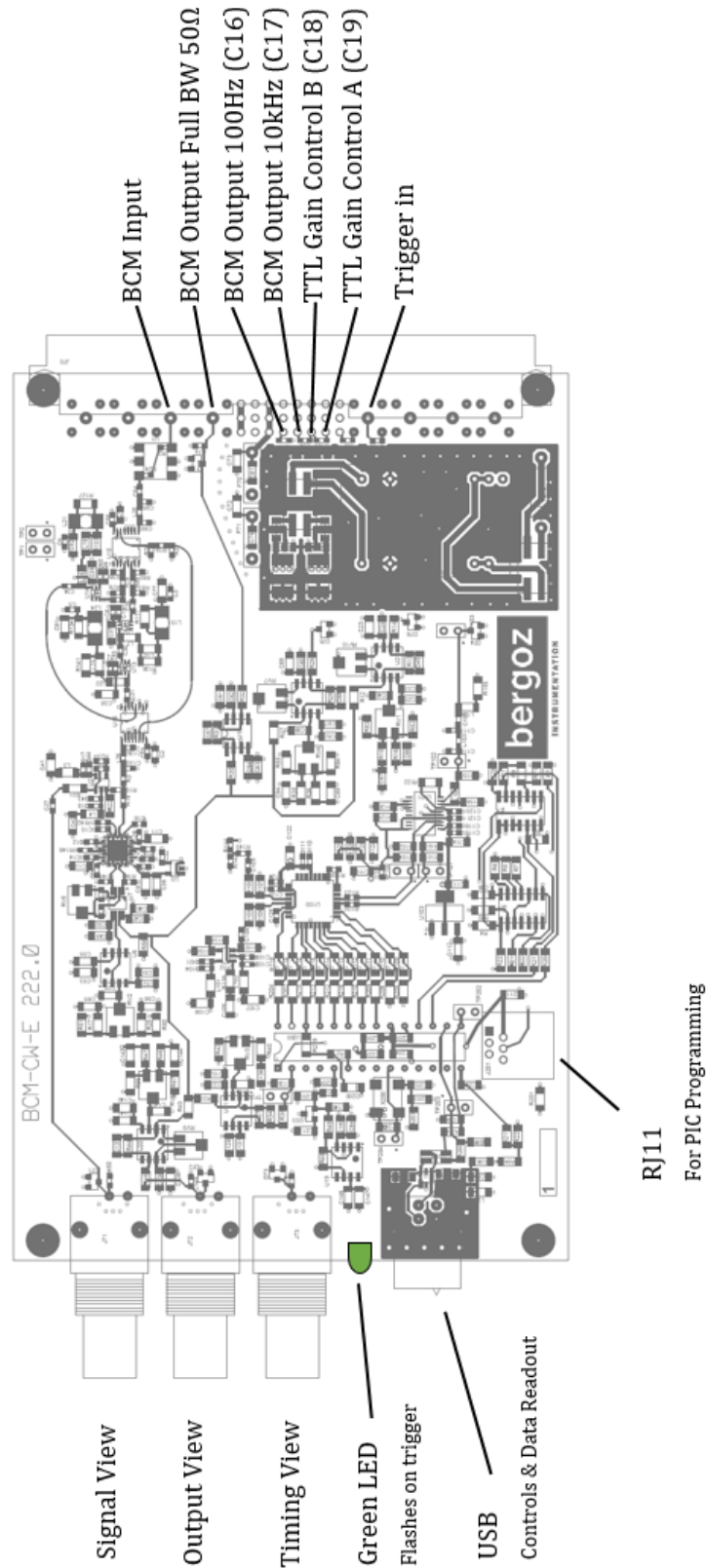
These commands do not change the BCM-CW-E configuration:

Command	Description	Command Frame (omitting termination)	Response Frame (omitting termination)	Comments
D	Read on-board digital delay line value as bit code	D0?	D0:zzzz=00000xxx	"xxx" is an integer number in HEX format within the range "000" to "3FF"
T	Read on-board digital delay line value in picoseconds	T0?	T0:zzzz=0000xxxx	"xxxx" is an integer number in HEX format within the range "0000" to "2374"
G	Read gain configuration as set by PIC	G0?	G0:zzzz=000000x	See previous table for a description of the data format.
X	Read gain configuration as set by hardware. (may differ from "G0?" if the gain is controlled via the DB9 port)	X0?	X0:zzzz=0000000x	See previous table for a description of the data format.
S	Read BCM-CW-E serial number	S0?	S0:zzzz=xxxxxxxx	"xxxxxxxx" is an integer number in HEX format within the range "00000000" to "FFFFFFFF"
F	Read BCM-CW-E firmware revision	F0?	F0:zzzz=xxxxxxxx	"xxxxxxxx" is an integer number in HEX format within the range "00000000" to "FFFFFFFF"
I	Read transfer function on/off state	I0?	I0:zzzz=0000001 I0:zzzz=0000000	on off
C	Read transfer function calibration constants	C0?	C0:zzzz=xxxxxxxx C1:zzzz=xxxxxxxx C2:zzzz=xxxxxxxx C3:zzzz=xxxxxxxx C4:zzzz=xxxxxxxx C5:zzzz=xxxxxxxx	"xxxxxxxx" is an integer number in HEX format within the range "00000000" to "FFFFFFFF". See previous table for further information.
R	Read transfer function scale	R0?	R0:zzzz=xxxxxxxx	"xxxxxxxx" is an integer number in HEX format within the range "00000000" to "FFFFFFFF". It is the exponent of the transfer function scale. E.g. if "xxxxxxxx" is -9, the transfer function value is in units of 1e-9 amperes, i.e. nA.

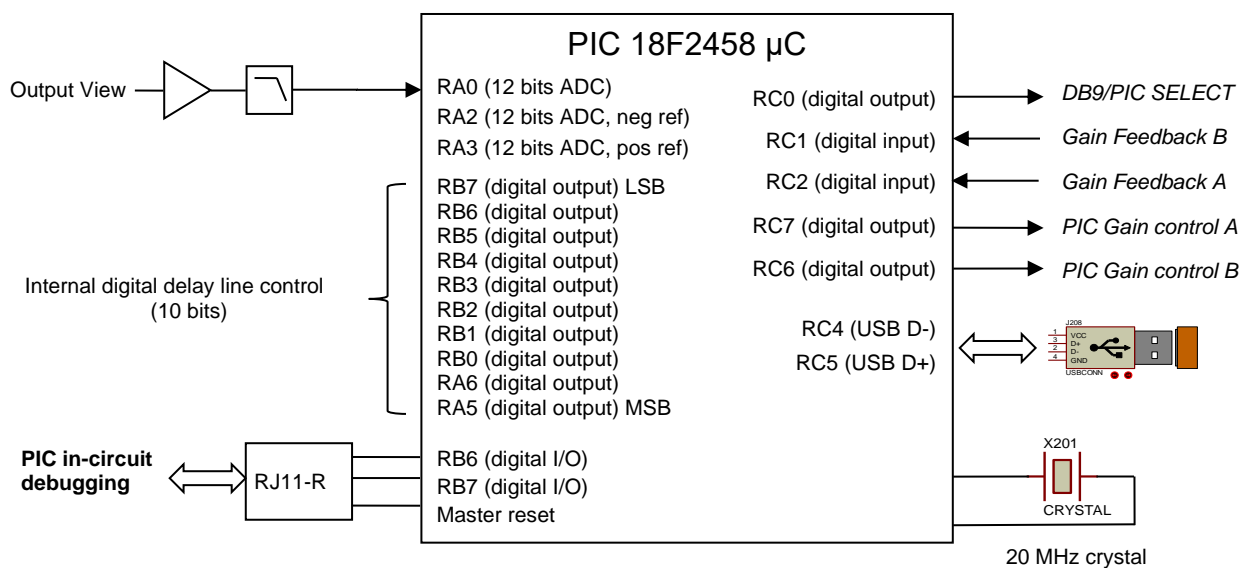
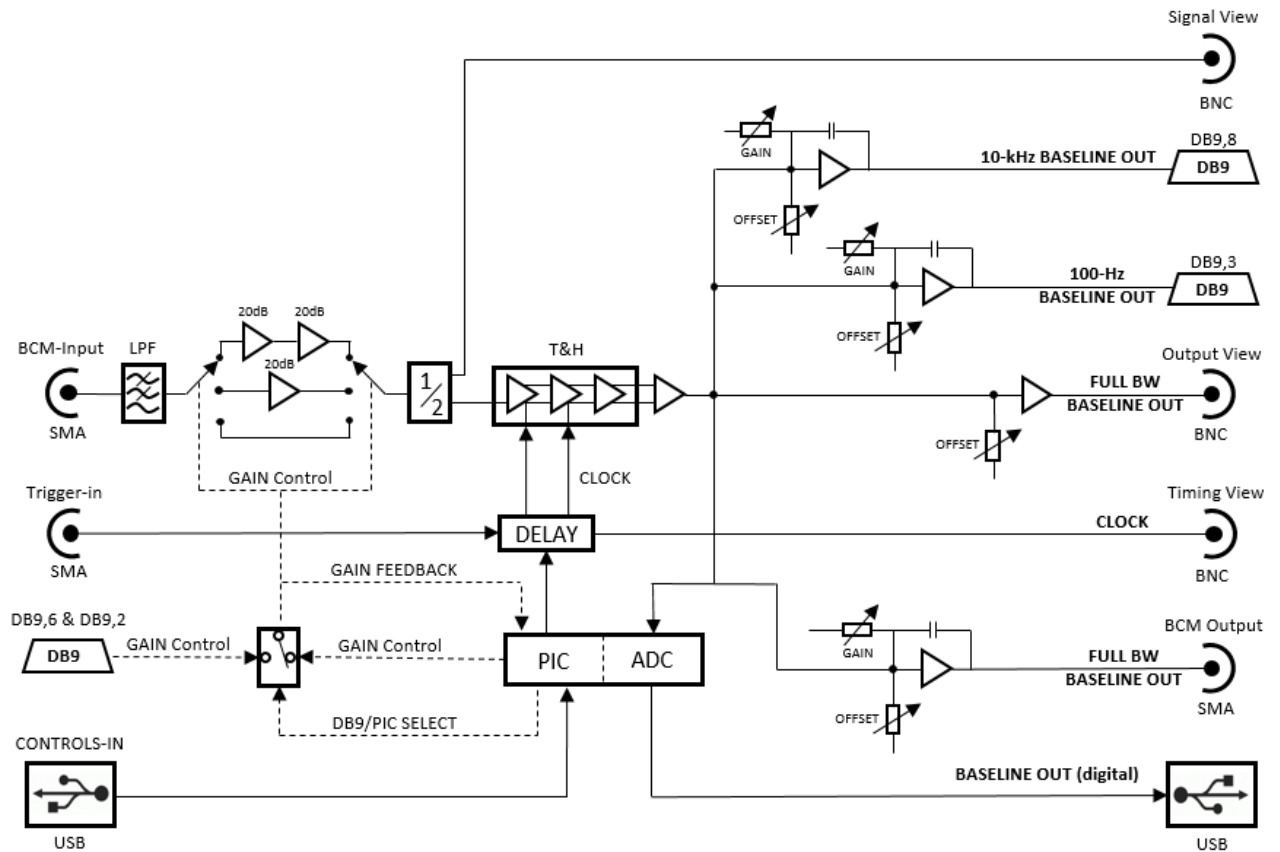
IDN	Read the BCM-CW-E identifier string	IDN? or *IDN?	<arb. string>	The response is a string of arbitrary format, e.g. "Bergoz, BCM-CW, S/N 000, FW 1.0"
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"zzzz" is a counter ranging from 0000 to FFFF which is incremented each time the BCM-CW-E tries to send data. After the counter reaches FFFF it is reset to 0000.

BCM-CW-E INPUTS / OUTPUTS



ARCHITECTURE



GENERAL SPECIFICATIONS

Beam RF	15 MHz ... 500 MHz
Full scale ranges	Refer to "Measured ranges" table chapter ³
Range Control	2 TTL lines on rear panel "Remote control" DB9 USB Control in front panel
Linearity error	< 1.5%

BCM Output (Rear panel SMA):

Nominal range	-1V ... +1V proportional to full scale current (into 50 Ω Load) -2V ... +2V (into High impedance)
Bandwidth	~ 1MHz (-3dB)
Uncertainty	+/- 0.5mV
Output impedance	50 Ω
Readout Impedance	50 Ω
Maximum Current Source/Sink	+/-20mA
Response Time	< 1 μ s (10%-90%)

Output View (Front panel BNC):

Output nominal	-4V ... +4V proportional to full scale current
Output over range	-4.1V ... +4.1V
Bandwidth	~350kHz (-3dB)
Uncertainty	+/- 2mV
Output impedance	100 Ω
Readout impedance	High impedance
Max. Current Source/Sink	+/-10mA
Response Time	< 1 μ s (10%-90%)

Remote control "DB9,3" (Rear panel DB9):

Nominal range	-4V ... +4V proportional to full scale current
Output over range	-4.1V ... +4.1V
Bandwidth	100Hz (-3dB)
Uncertainty	+/- 2mV
Output impedance	100 Ω
Readout impedance	High impedance
Max. Current Source/Sink	+/-10mA

³ Attenuators or low-noise amplifier may be inserted in BCM input to lower or increase the full-scale ranges.

Remote control "DB9,8" (Rear panel DB9):

Output nominal	-4V ... +4V proportional to full scale current
Output over range	-4.1V ... +4.1V
Bandwidth	10kHz (-3dB)
Uncertainty	+/- 2mV
Output impedance	100Ω
Readout impedance	High impedance
Max. Current Source/Sink	+/-10mA

Trigger in (Rear panel SMA):

Signal:	Sinewave	Pulse
Amplitude range	-35dBm ... 0dBm	20mVp-p ... 200mVp-p
Amplitude Max	+4dBm	500mVp-p
Triggering Edge	Falling edge	Falling edge
Duty Cycle	-	50%
Input Impedance	50Ω	50Ω

BCM Input (Rear panel SMA):

Input range	-1V... +1V
Input impedance	50Ω

Timing View (Front panel BNC):

Nominal output range	~ 40mVp-p (into 50 Ω)
Readout impedance	50Ω
Risetime	~ 350ps (10%-90%)

Signal View (Front panel BNC):

Nominal range	-0.5V... +0.5V (into 50 Ω)
Output over range	-1.1V ... +1.1V (into 50 Ω)
Bandwidth	~ 270MHz (-3dB)
Readout impedance	50Ω

Remote control "DB9,6" (Rear panel DB9):

Logical input TTL compatible

Remote control "DB9,2" (Rear panel DB9):

Logical input TTL compatible

USB (Rear panel):

Type B connector, compatible to USB 2.0 standard

Measured ranges

Typical performances and measurement ranges:

BEAM DUTY CYCLE		50%	33%
0dB GAIN	Max	100mA	66.6 mA
	Uncertainty	+/- 100µA	+/- 100µA
20dB GAIN	Max	20mA	10mA
	Uncertainty	+/- 10µA	+/- 10µA
40dB GAIN	Max	2mA	1mA
	Uncertainty	+/- 1µA	+/- 1µA

To overcome above current full-scale ranges, attenuators can be inserted in BCM Input located on the chassis rear panel.

BCM-CW-E specifications

Rear module connector DIN 41612-M / 24+8 male, with 1.0/2.4 coaxial inserts

Power consumption +15 V, 220 mA (Max) / -15 V, 220 mA (Max)

Card size 3U x 4F, Eurosize 100 x 160 mm, 20 mm wide

Input signals, output signals and other interfaces



BCM-CW-E Front Panel

Signal View

Output View

Timing View

USB



BCM-RFC Rear Panel

Remote control: DB9 connector

Pin DB9,6: TTL Input A

Pin DB9,2: TTL Input B

Pin DB9,8: Baseline output (10 kHz)

Pin DB9,3: Baseline output (100 Hz)

Pins DB9,1 DB9,4 DB9,5 DB9,7 DB9,9: connected to GND

BCM Input

BCM Output

Trigger in

Connectors and pin allocation

BCM-CW-E Front panel BNC connectors					
RF-Chassis Rear SMA connectors					
DB9 female connector on BCM-RFC rear panel					
DIN41612M BCM-CW-E module rear connector					
INPUT SIGNALS					
BCM-CW-E Input 50 Ω (to connect to CWCT)	BCM Input	B8 ⁴		SMA1	
INPUT CONTROLS					
TTL INPUT A (Gain Control)	DB9,6	C19	DB9,6		
TTL INPUT B (Gain Control)	DB9,2	C18	DB9,2		
OUTPUT SIGNALS					
BCM-CW-E Baseline output Full BW 50 Ω	BCM Output	B11 ⁴		SMA2	
BCM-CW-E Baseline output (100 Hz)	DB9,3	C16	DB9,3		
BCM-CW-E Baseline output (10 kHz)	DB9,8	C17	DB9,8		
BNC front-panel MONITORING					
CWCT signal view after Amplification 50 Ω	Signal View				BNC 1
BCM-CW-E Baseline output Full BW	Output View				BNC 2
Baseline Sampling Clock output	Timing View				BNC 3
EXTERNAL TRIGGER INPUT					
Trigger input 50 Ω	Trigger in	B22 ⁴		SMA3	
POWER SUPPLY					
+15 V	+15 V	A13 B13 C13			
-15 V	-15 V	A15 B15 C15			
Common (GND)	COM	A14 B14 C14	DB9,1 DB9,4 DB9,5 DB9,7 DB9,9		

⁴ coaxial insert 1.0/2.3 type

RECOMMENDATIONS ABOUT CABLES AND INSTALLATION

CWCT and BCM-CW-E system performance are measured and guaranteed when a Bergoz Instrumentation-supplied interconnect cable BCM-C/xx or BCM-RHC/xx is used. It is double-shielded radiation tolerant coaxial cable to reject RFI. It is fitted at each end by two CMC common-mode chokes for EMI rejection:

- MnZn ferrite core for high-frequency >500 MHz rejection;
- Iron-based nanocrystalline Finemet core with soft B-H loop for low frequency rejection.

Unnecessary intermediate bulkheads should be avoided. When for practical reasons bulkheads must be used, e.g., on patch-panels, it is preferable that the bulkhead body is isolated from ground. On either side of the patch-panel a set of two CMC common-mode chokes must be installed on the cable. This is required to assure EMI rejection.

SMA connectors at both ends of a Bergoz Instrumentation-supplied cable feature different dielectric types depending on cable reference:

- Standard BCM-C/xx cable is fitted with PTFE (Teflon) dielectric SMA at both ends. PTFE radiation tolerance R.I.~2 (source H. Schönbacher CERN 98-01).
- Radiation-tolerant BCM-RHC/xx cable is fitted with PEEK (Victrex) dielectric SMA at both ends. PEEK radiation tolerance R.I.>7 (same source).

BCM-CW system, i.e., chassis and modules should –as much as possible– be kept away from high power RF equipment, klystrons, cavities.

If the user procures the CWCT interconnect cable from a source other than Bergoz Instrumentation, cable must be double shielded, connectors must be chosen carefully according to the cable specifications, connector dielectric should conform to the radiation environment, appropriate common-mode chokes must be installed at each end of every cable segment. A cable segment is any segment of cable between two connectors or bulkheads.

Cable and connectors manufacturer's instructions must be followed meticulously. If the cable assembly is subcontracted, subcontractors must be informed of the extreme reliability expected from these cables. Transmission and reflections of each cable must be measured before installation with a network analyzer, over a frequency band up to twice the operating frequency.

BCM-CW-E modules must be installed in a RF-shielded chassis, BCM-RFC/xx or equivalent.

ACCESSORIES

BCM Chassis: ref. BCM-RFC/xx

The BCM-RFC/xx chassis is built on a 19" Schroff rackable RF chassis.

Bin dimensions: 3U x 84F

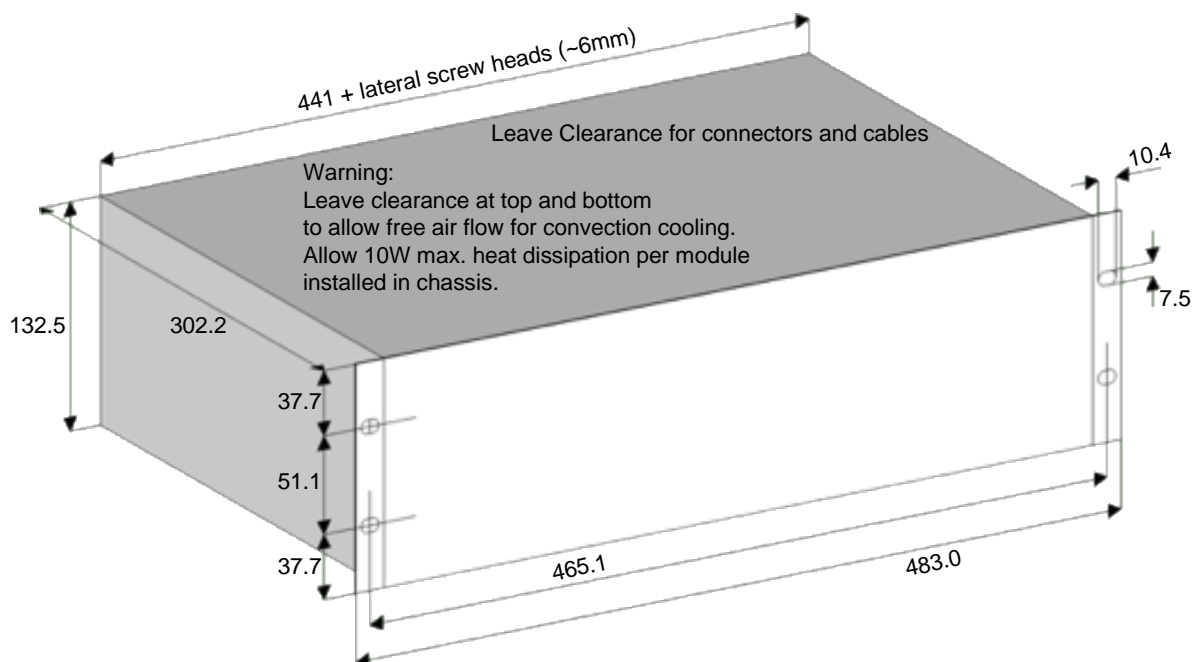
Schroff reference: Europac Lab HF/RF #20845-283

The BCM-RFC/xx can be wired with up to 16 BCM-E stations, xx being the number of wired stations (e.g. one BCM-CW-E module per station).

BCM-RFC/xx ordered with less than 16 wired stations are partially wired to allow future field-upgrades.

Unwired stations are masked with RF-shielded blank panels.

BCM-RFC/xx outer dimensions



SCHEMATICS & BOARD LAYOUT

Schematics and board layouts remain the exclusive property of Bergoz Instrumentation at any time. They are protected by the copyright laws.

Schematics and board layouts are not delivered with the instruments.

ACKNOWLEDGEMENTS

Based on our extensive knowledge of current transformers and analog electronics, the CWCT and the BCM-CW-E were designed by Hervé Bayle, Laurent Dupuy, Frank Stulle and Julien Bergoz.

Early sampling prototypes were developed by Hanjiao Chen, SINAP, Shanghai, during his internship at Bergoz Instrumentation.

Saint Genis Pouilly, October 2020

ANNEX I

	3.3V/5V 2.5GHz PROGRAMMABLE DELAY	ECL Pro® SY100EP195V
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FEATURES

- Pin-for-pin, plug-in compatible to the ON Semiconductor MC100EP195
- Maximum frequency > 2.5GHz
- Programmable range: 2.2ns to 12.2ns
- 10ps increments
- PECL mode operating range: $V_{CC} = 3.0V$ to $5.5V$ with $V_{EE} = 0V$
- NECL mode operating range: $V_{CC} = 0V$ with $V_{EE} = -3.0V$ to $-5.5V$
- Open input default state
- Safety clamp on inputs
- A logic high on the /EN pin will force Q to logic low
- D[0:10] can accept either ECL, CMOS, or TTL inputs
- V_{BB} output reference voltage
- Available in a 32-pin TQFP package



ECL Pro®

DESCRIPTION

The SY100EP195V is a programmable delay line, varying the time a logic signal takes to traverse from IN to Q. This delay can vary from about 2.2ns to about 12.2ns. The input can be PECL, LVPECL, NECL, or LVNECL.

The delay varies in discrete steps based on a control word presented to SY100EP195V. The 10-bit width of this latched control register allows for delay increments of approximately 10ps.

An eleventh control bit allows the cascading of multiple SY100EP195V devices, for a wider delay range. Each additional SY100EP195V effectively doubles the delay range available.

For maximum flexibility, the control register interface accepts CMOS or TTL level signals, as well as the input level at the IN± pins.

All support documentation can be found on Micrel's web site at: www.micrel.com.

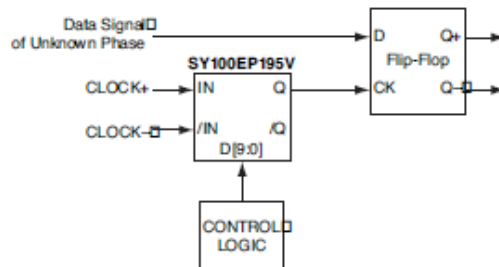
APPLICATIONS

- Clock de-skewing
- Timing adjustment
- Aperture centering

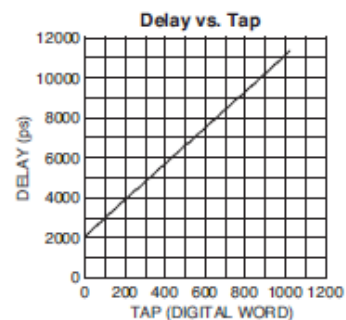
CROSS REFERENCE TABLE

Micrel Semiconductor	ON Semiconductor
SY100EP195VTI	MC100EP195FA
SY100EP195VTITR	MC100EP195FAR2

TYPICAL APPLICATIONS CIRCUIT



TYPICAL PERFORMANCE



ECL Pro is a registered trademark of Micrel, Inc.

Micrel, Inc.

ECL Pro®
 SY100EP195V

AC ELECTRICAL CHARACTERISTICS

V_{CC} = 3.0 to 5.5V, V_{EE} = 0V or V_{CC} = 0V, V_{EE} = -3.0 to -5.5V; T_A = -40°C to +85°C.^(12, 13)

Symbol	Parameter	T _A = -40°C			T _A = +25°C			T _A = +85°C			Unit	
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max		
f _{MAX}	Maximum Frequency ⁽¹⁴⁾		2.5			2.5			2.5		GHz	
t _{PD}	Propagation Delay											
	IN to Q; D[0-10]=0	1650	2000	2450	1800	2050	2600	1950	2250	2750	ps	
	IN to Q; D[0-10]=1023	9500	11500	13500	9800	12200	14000	10600	13300	15800	ps	
	/EN to Q; D[0-10]=0	1600	2150	2600	1800	2300	2800	2000	2500	3000	ps	
	D10 to CASCADE	300	420	500	325	450	550	325	525	625	ps	
t _{RANGE}	Programmable Range t _{PD(max)} -t _{PD(min)}	7850	9450		8200	10000		8850	10950		ps	
Δt	Step Delay ⁽¹⁵⁾	D0 High		9		10			10		ps	
		D1 High		25		26			27		ps	
		D2 High		42		42			43		ps	
		D3 High		75		80			81		ps	
		D4 High		142		143			150		ps	
		D5 High		296		300			310		ps	
		D6 High		532		540			565		ps	
		D7 High		1080		1095			1140		ps	
		D8 High		2100		2150			2250		ps	
		D9 High		4250		4300			4500		ps	
Lin	Linearity ⁽¹⁶⁾		±10		±10			±10		%LSB		
t _{SKEW}	Duty Cycle Skew ⁽¹⁷⁾ t _{PHL} -t _{PLH}					25				ps		
t _S	Setup Time	D to LEN	200	0	200	0		200	0		ps	
		D to IN ⁽¹⁸⁾	300	140	300	160		300	180		ps	
		/EN to IN ⁽¹⁹⁾	300	150	300	170		300	180		ps	
t _H	Hold Time	LEN to D	200	60	200	100		200	80		ps	
		IN to /EN ⁽²⁰⁾	400	250	400	280		400	300		ps	
t _R	Release Time	/EN to IN ⁽²¹⁾				500					ps	
		SETMAX to LEN	400	200	400	250		400	300		ps	
		SETMIN to LEN	350	275	350	200		350	335		ps	
t _{JIT}	Cycle-to-Cycle Jitter ⁽²²⁾		0.2	< 1		0.2	< 1		0.2	< 1	psRMS	
V _{PP}	Input Voltage Swing (Differential)	150	800	1200	150	800	1200	150	800	1200	mV	
t _r	Output Rise/Fall Time	20% to 80% (Q)		180	250		210	300		230	325	ps
		20% to 80% (CASCADE)		180	250		210	300		230	325	ps

Notes:

12. AC characteristics are guaranteed by design and characterization.
13. Measured using 750mV source, 50% duty cycle clock source, R_L = 50Ω to V_{CC} - 2V.
14. Refer to "Typical Operating Characteristics" for output swing performance.
15. The delays of the individual bits are cumulative.
16. Linearity is the deviation from the ideal delay.
17. Duty cycle skew guaranteed only for differential operation measured from the crosspoint of the input edge to the crosspoint of the corresponding output edge.
18. Setup time defines the amount of time prior to an edge on IN, /IN that the D[0:9] bits must be set to guarantee the new delay will occur for that edge.
19. Setup time is the minimum that /EN must be asserted prior to the next transition of IN, /IN to prevent an output response greater than ±75mV to that IN, /IN transition.
20. Hold time is the minimum time that /EN must remain asserted after a negative going IN or a positive going /IN to prevent an output response greater than ±75mV to that IN, /IN transition.
21. Release time is the minimum time that /EN must be deasserted prior to the next IN, /IN transition to ensure an output response that meets the specified IN to Q propagation delay and transition times.
22. This is the amount of generated jitter added to an otherwise jitter free clock signal, going from IN, /IN to Q, /Q, where the clock may be any frequency between 0.0 and 2.5GHz.