156 rue du Mont Rond
Espace Allondon Ouest
01630 Saint Genis Pouilly, France

Tel: +33 450 42 66 42
Fax: +33 450 42 66 43
Email: info@bergoz.com

CWCT & BCM-CW-E

CW Current Transformer
Beam Charge Monitor for CW beams and Macropulses

User's Manual

Rev. 1.0

Japan

Hayashi-Repic Co., Ltd.
www.h-repic.co.jp
sales@h-repic.co.jp

U.S.A.

GMW Associates
ww.gmw.com
sales@gmw.com

China

Beijing Conveyi Limited
ww.conveyi.com
sales@conveyi.com

India

GEEBEE International
www.geebeeinternational.com
info@geebeeinternational.com

Record of updates

Version	Date	Updates performed
1.0	04/2018	First release

TABLE OF CONTENTS

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 and fax number of the user. Contact Bergoz Instrumentation or your local distributor to determine where to return the product. Returns must be notified by fax 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 Neutral 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 Neutral 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 222.0 with firmware 1.0 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 with PTFE connectors
- Option: BCM-RHC/xx CWCT to BCM-RFC chassis interconnect coaxial cable in PEX 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.

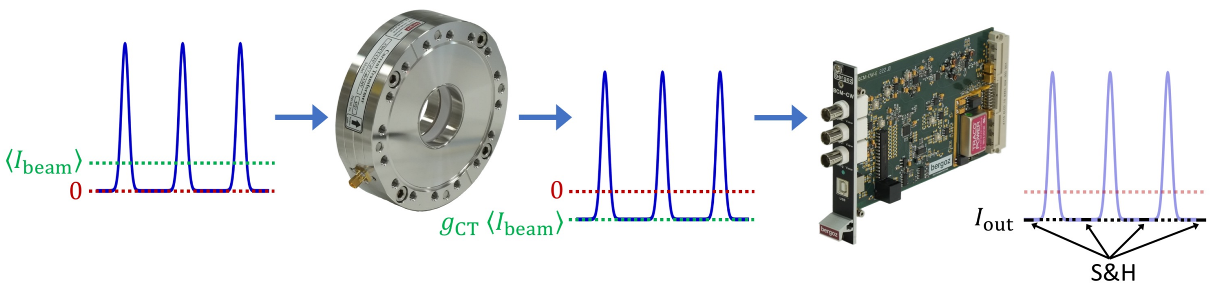
Power supply must however be dimensioned according to power consumption. Please contact Bergoz Instrumentation before adding more BCM modules into a chassis.

GENERAL DESCRIPTION

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, yet low enough to tend to an output signal duty factor close to 50%.

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[1]. 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 10 ns in 10 ps 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 communication is done via specific USB commands, e.g. the BCM-CW-E graphical user interface (GUI). Details on the GUI and USB communication are described in this manual.

Note: The GUI provided is an example of how to use controls. It allows to check the instrument upon delivery.

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.

[1] Patent pending EP17020307.9

In-flange models

In-flange models are current transformers whose core(s) are embedded in a pair of flanges. Flanges can be Conflat, ISO, KF, Dependex, EVAC or specials with usual inner diameters. CWCT 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 it is made from a selection of higher temperature alloys and materials:

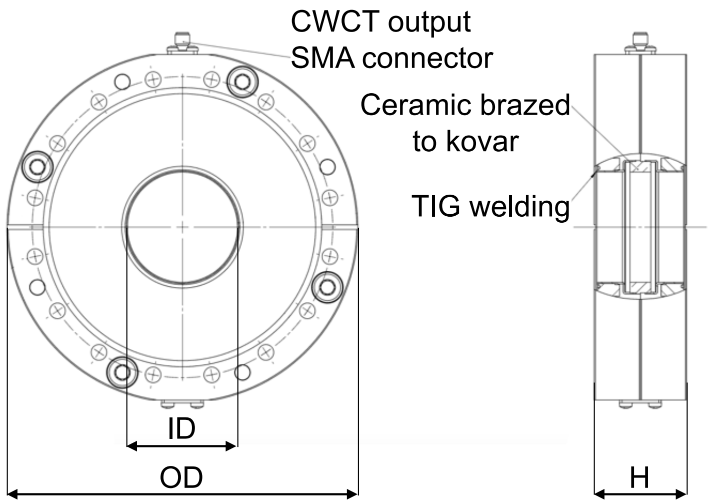
- Option BK150C allows bake out at 150°C (300°F)
- Option BK185C allows bake out at 185°C (365°F)
- Option BK200C allows bake out at 200°C (392°F)

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 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
-xx.x	xx.x is the sensitivity of the sensor [V/A]
Example: CWCT-CF6"-60.4-40-UHV-5.0	
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

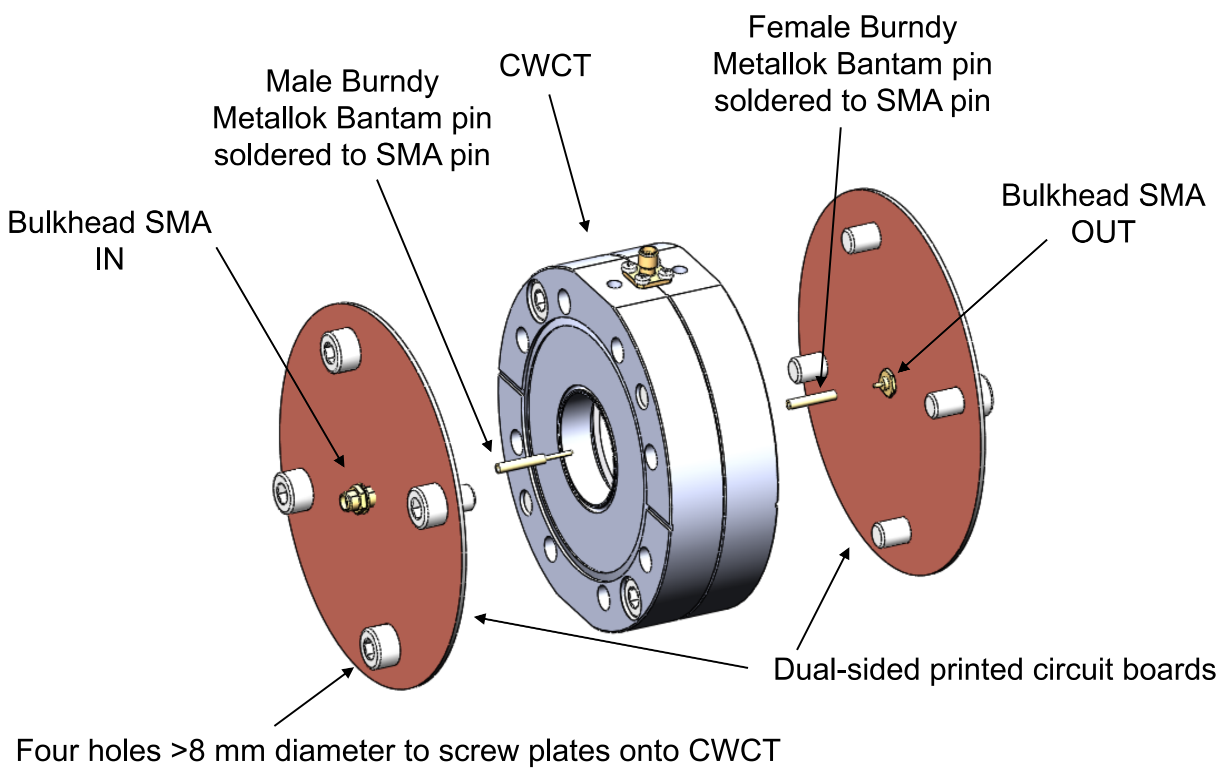
QUICK CHECK

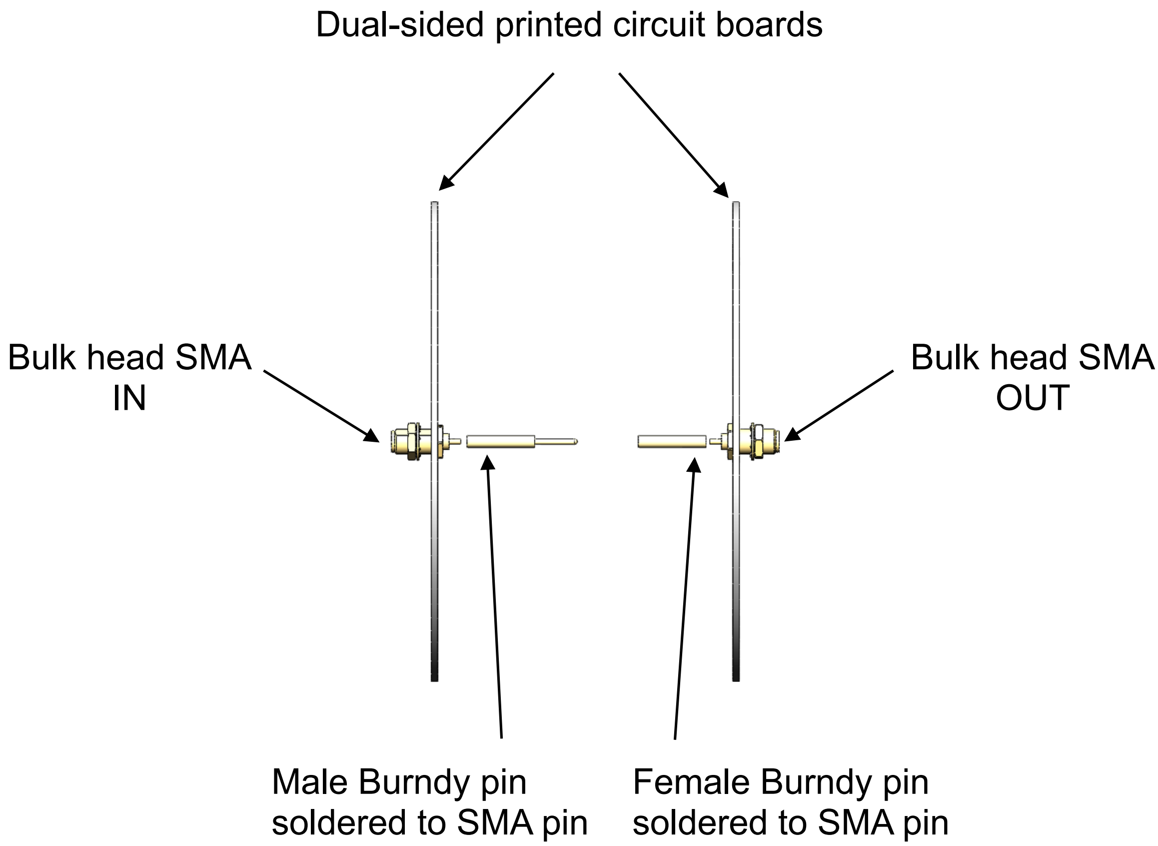
Before installation in the accelerator, a few bench tests can be performed to get familiar with the CWCT and the BCM-CW-E.

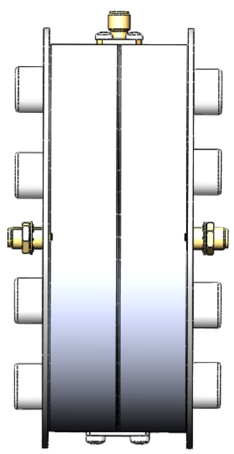
Current Transformer Test Fixture

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:




Dual-sided printed circuit boards
Bulk head SMA IN
Bulk head SMA OUT
Male Burndy pin soldered to SMA pin
Female Burndy pin soldered to SMA pin



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 MΩ readout).

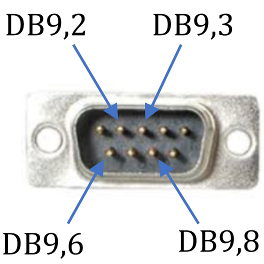
Timing View:
When displayed together with "Signal View", shows triggering point reference (zero crossing) of baseline measurement reference (tunable via USB) (50 Ω readout)[2].

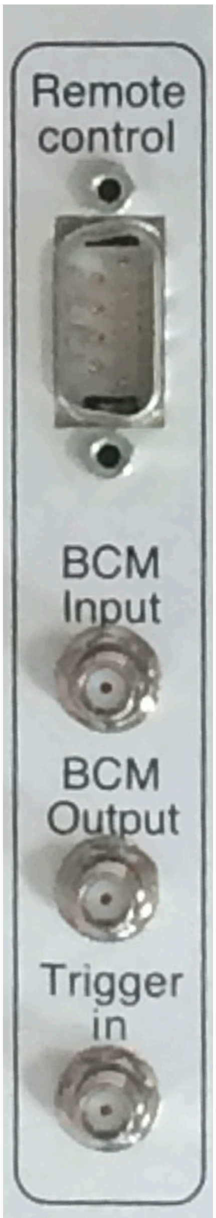
Front panel LED:
Flashes when BCM-CW-E is triggered.

USB connector type B:
Data readout and remote control.

[2] 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 MΩ readout).

Pin DB9,3: Baseline output – 100 Hz bandwidth
Output voltage proportional to the average beam current (1 MΩ 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 1µs, permitting fast detection of beam loss.

Trigger in:
Synchronized to Beam RF
Duty cycle: 20% … 80%
20mVp-p to 60mVp-p Maximum, 50 Ω terminated.

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

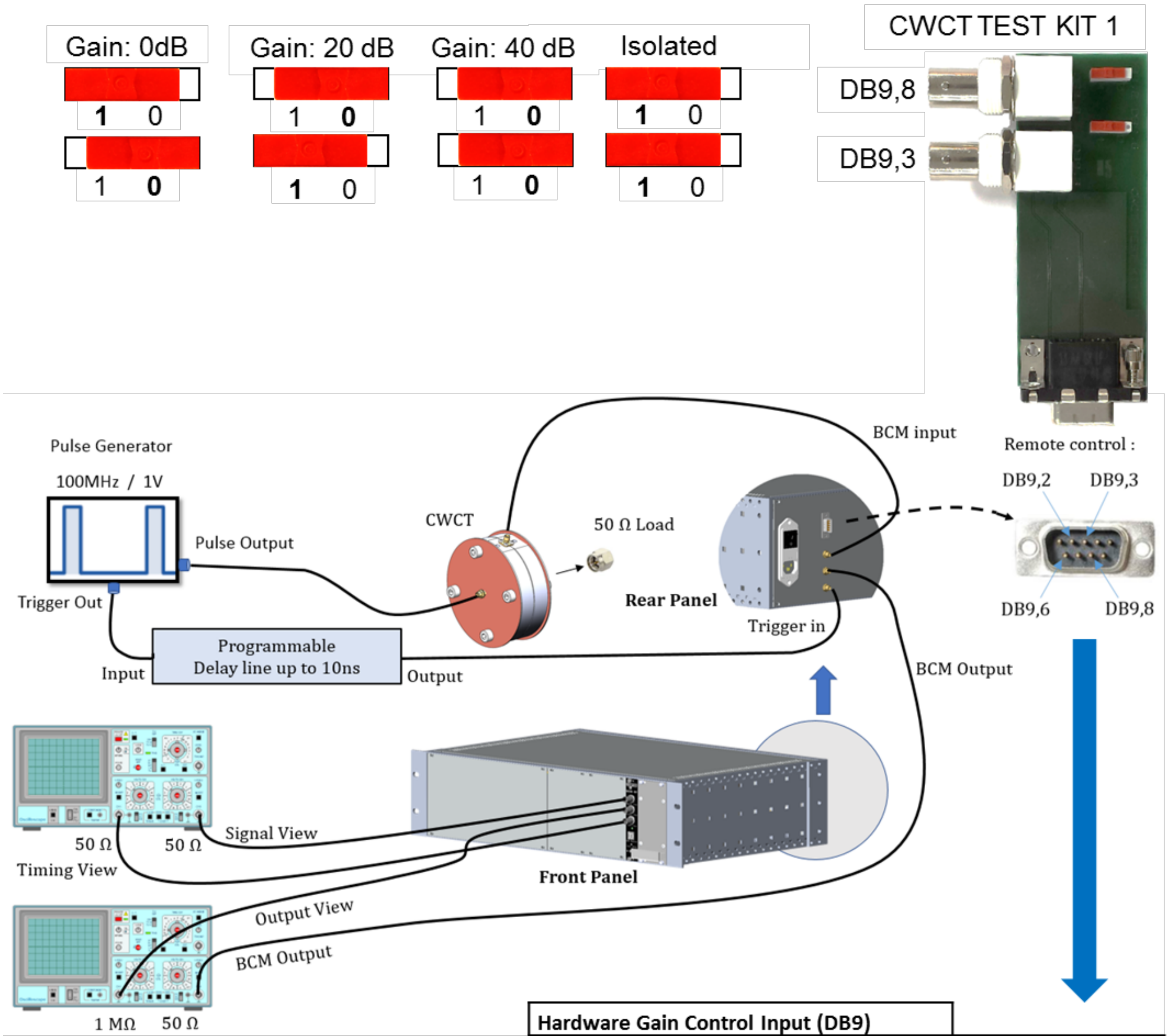
BCM-CW-E + CWCT Current Measurement Example Setup

What is needed:

- CWCT
- Current Transformer test fixture (see description page 8)
- BCM-CW-E electronics module
- BCM-RFC/xx chassis
- RF Pulse generator, 100MHz minimum, with a 50% Duty cycle trigger output
- Programmable delay line allowing delay adjustment up to 10ns 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)		
DB9,6	**DB9,2**	**Input Gain**
OPEN (High)	OPEN (High)	ISOLATED
GROUNDED (Low)	OPEN (High)	Gain: 0dB
OPEN (High)	GROUNDED (Low)	Gain: 20dB
GROUNDED (Low)	GROUNDED (Low)	Gain: 40dB

After USB controls have been applied to BCM-CW-E, it may be left in a state other than Ex-factory default state. E.g., control via DB9 may be disabled

1) At time of initial shipment, the AC mains voltage is set according to the country of destination. A label on the power supply units 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 60mVp-p, insert attenuators till signal is in range 20mVp-p … 60mVp-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
GROUNDED (Low)	OPEN (High)	Gain: 0dB
OPEN (High)	GROUNDED (Low)	Gain: 20dB
GROUNDED (Low)	GROUNDED (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.

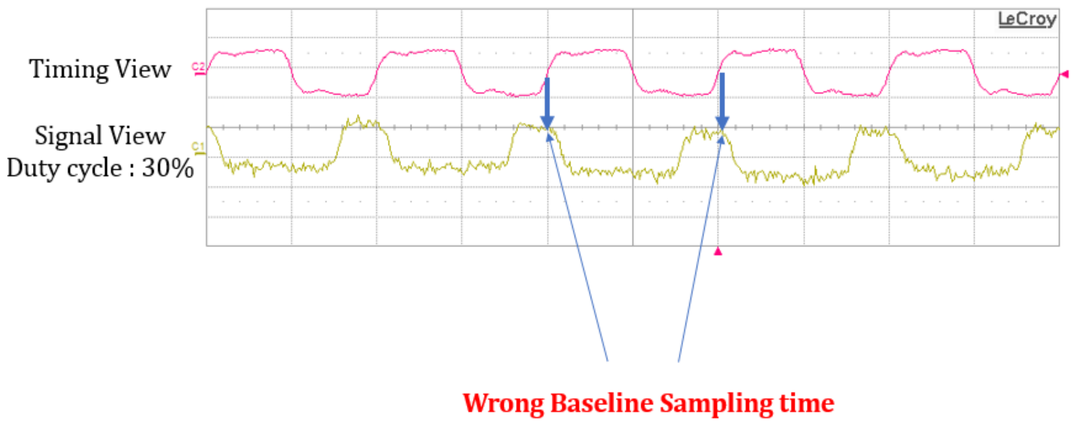
DB9,6 to be connected to any GND Pin:
DB9,1 DB9,4 DB9,5 DB9,7 DB9,9

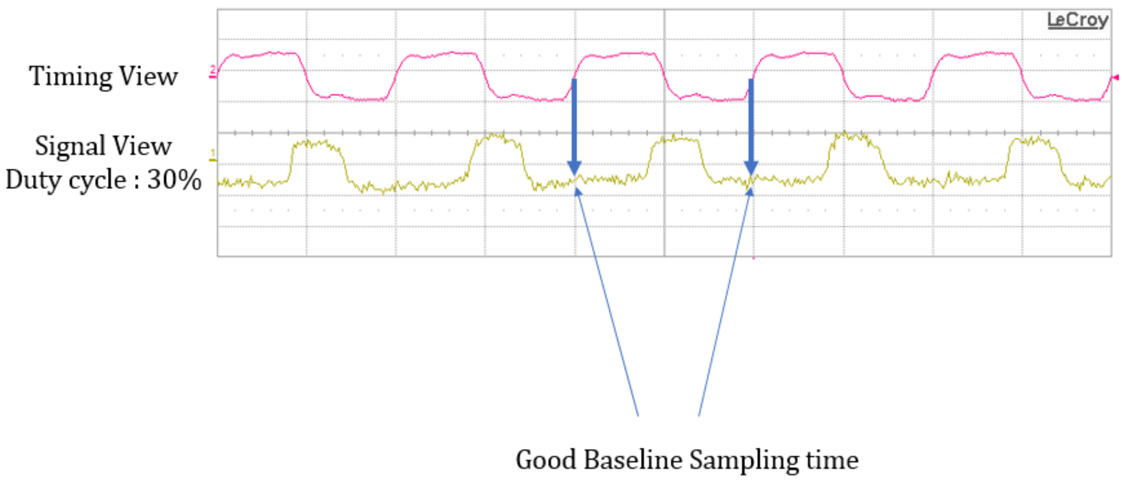

DB9,6

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.

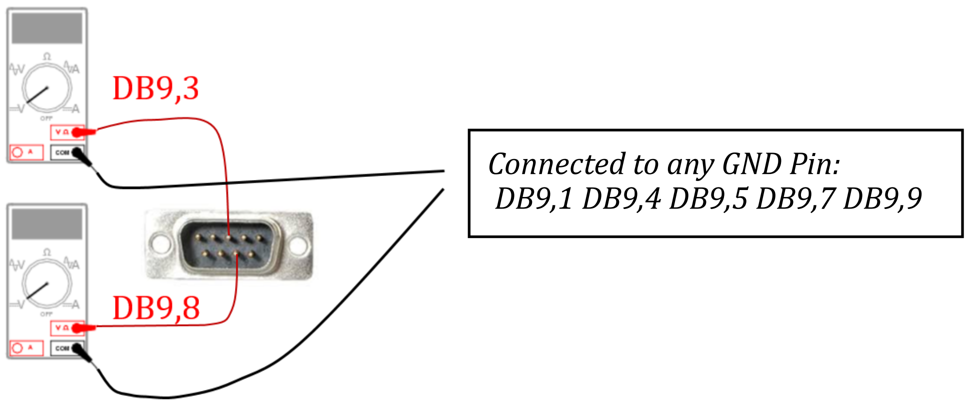




In case "Signal View" is not well visible, select a higher Gain.

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 voltage outputs are proportional to the average current going through the CWCT.

The voltage to current Factor is indicated in the calibration report.

It depends on the following:

- CWCT sensitivity 5.0, 2.5 or 1.25V/A
- Input Gain
- BCM Output port

VOLTAGE TO CURRENT FACTOR

Typical voltage to current Factor Table:

							Voltage to current Factor (A/V)		
Output Port	Bandwidth	Connector Type	Connector Location	Readout Impedance	Voltage Range	Gain	CWCT 5.0V/A	CWCT 2.5V/A	CWCT 1.25V/A
"Output View"	Full BW	BNC	Front Panel	1 MΩ	+ / - 4V	40 dB	5,0E-04	1,0E-03	2,0E-03
"DB9,8"	1 kHz	DB9	Rear Panel	1 MΩ	+ / - 4V	40 dB	5,0E-04	1,0E-03	2,0E-03
"DB9,3"	10 Hz	DB9	Rear Panel	1 MΩ	+ / - 4V	40 dB	5,0E-04	1,0E-03	2,0E-03
"BCM Output"	Full BW	SMA	Rear Panel	50 Ω	+ / - 1V	40 dB	2,0E-03	4,0E-03	8,0E-03
"Output View"	Full BW	BNC	Front Panel	1 MΩ	+ / - 4V	20 dB	5,0E-03	1,0E-02	2,0E-02
"DB9,8"	1 kHz	DB9	Rear Panel	1 MΩ	+ / - 4V	20 dB	5,0E-03	1,0E-02	2,0E-02
"DB9,3"	10 Hz	DB9	Rear Panel	1 MΩ	+ / - 4V	20 dB	5,0E-03	1,0E-02	2,0E-02
"BCM Output"	Full BW	SMA	Rear Panel	50 Ω	+ / - 1V	20 dB	2,0E-02	4,0E-02	8,0E-02
"Output View"	Full BW	BNC	Front Panel	1 MΩ	+ / - 4V	0 dB	5,0E-02	1,0E-01	2,0E-01
"DB9,8"	1 kHz	DB9	Rear Panel	1 MΩ	+ / - 4V	0 dB	5,0E-02	1,0E-01	2,0E-01
"DB9,3"	10 Hz	DB9	Rear Panel	1 MΩ	+ / - 4V	0 dB	5,0E-02	1,0E-01	2,0E-01
"BCM Output"	Full BW	SMA	Rear Panel	50 Ω	+ / - 1V	0 dB	2,0E-01	4,0E-01	8,0E-01

IMPORTANT NOTE
The voltage to current Factor (A/V) are NOMINAL values. Precise calibrated Factors are stated for the ordered configuration in the calibration report.

E.g. Assuming the following Configuration:
Use of a CWCT 5.0 V/A
Gain = 20dB
"Output View" = 1,2V

The corresponding Average Beam Current = 1,2 x 5.00E-03 = 6.00E-03 A

TEMPERATURE DEPENDENCE OF THE CWCT AND BCM-CW-E

The signals delivered by the CWCT and the BCM-CW-E depend weakly on temperature. The corresponding temperature coefficients are factory-measured and provided on the sheet "Temperature Dependence" delivered with the product.

The necessary corrections can be applied to the measured voltage:

$$\begin{aligned} U_{\mathrm{BCM-CW,corr}} = U_{\mathrm{BCM-CW,meas}} &- c^{\mathrm{U}}_{\mathrm{BCM-CW}}\,(T_{\mathrm{BCM-CW}} - T_{\mathrm{Cal}}) \\ &- c^{\mathrm{U}}_{\mathrm{CWCT}}\,(T_{\mathrm{CWCT}} - T_{\mathrm{Cal}}) \end{aligned}$$

The corrected voltage is then used to determine the average input current.

$c^{\mathrm{U}}_{\mathrm{BCM-CW}}$ = Temperature coefficient of the output voltage with respect to changes of the BCM-CW-E temperature

$c^{\mathrm{U}}_{\mathrm{CWCT}}$ = Temperature coefficient of the output voltage with respect to changes of the CWCT temperature

$T_{\mathrm{BCM-CW}}$ = Ambient temperature outside the BCM-RFC/xx chassis

T_{CWCT} = Ambient temperature at the CWCT location

T_{Cal} = Ambient temperature during BCM-CW-E and CWCT calibration

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 operating system 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.

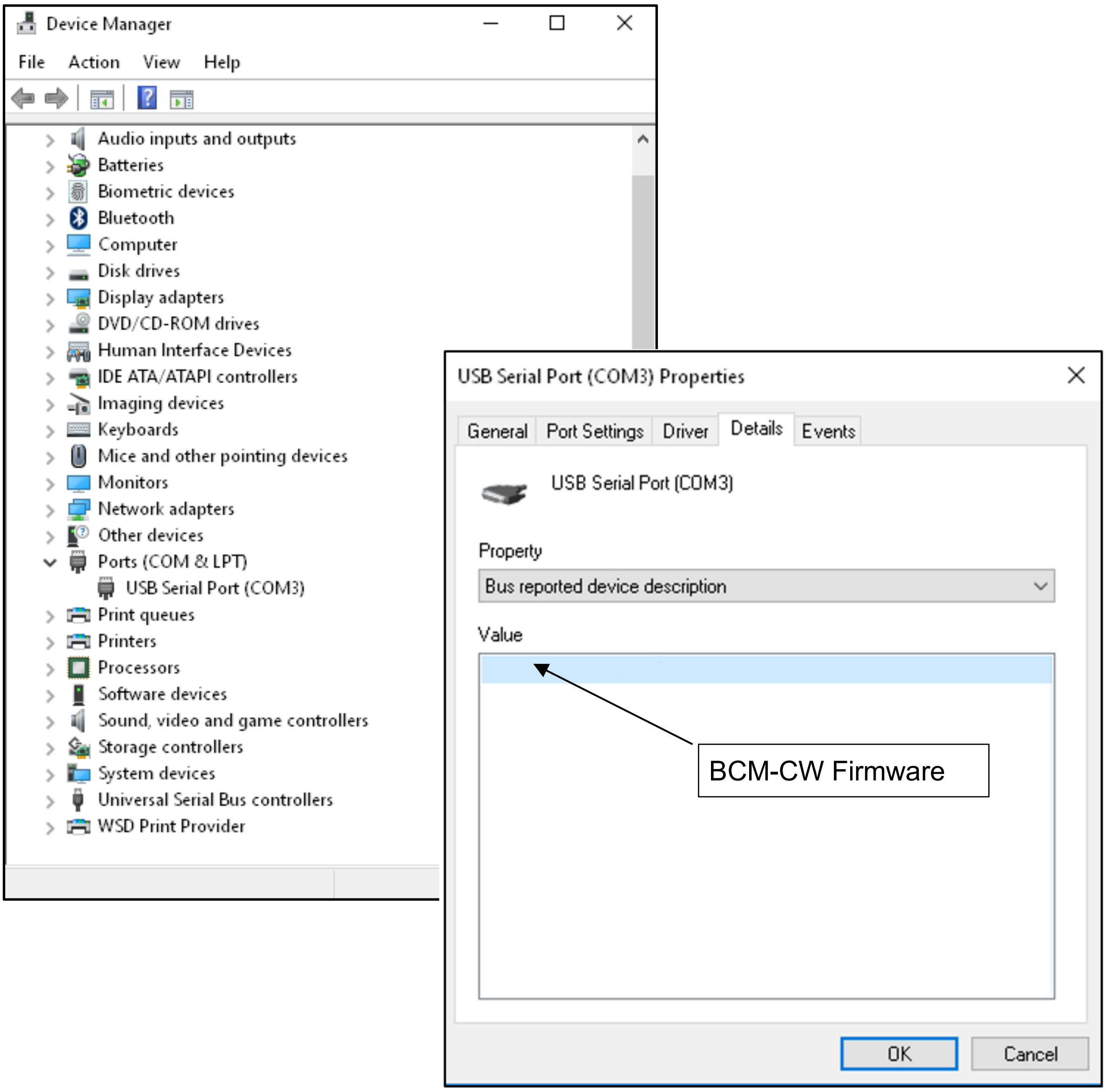
The Microchip USB CDC serial driver might be required on Windows systems to communicate with the BCM-CW-E. This driver is part of the Microchip Libraries for Applications (USB). It is also provided with the BCM-CW-E or can be obtained from Bergoz Instrumentation upon request to info@bergoz.com

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

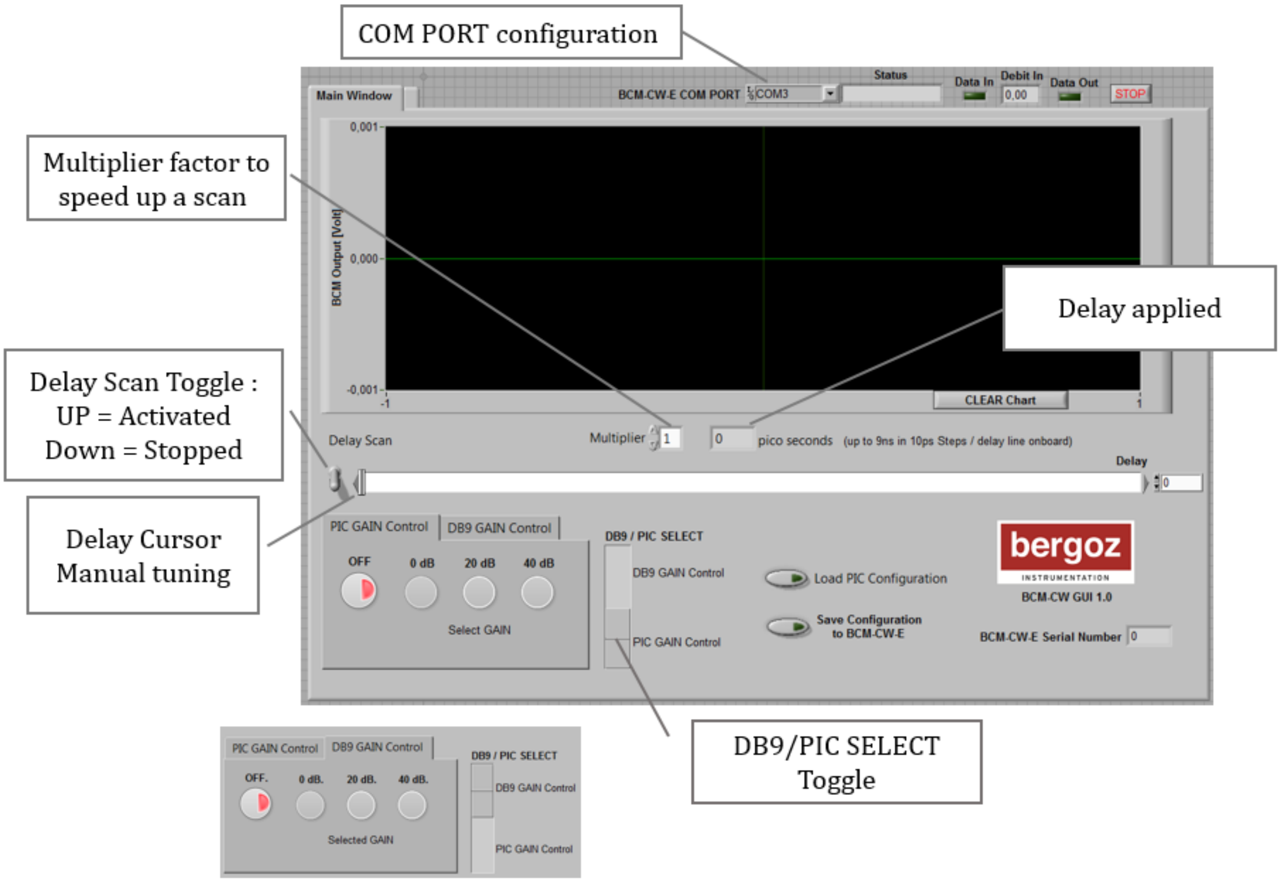
1) Connect the USB cable from the BCM-CW-E front panel USB port to the PC.
2) Windows automatically recognizes the device and loads the USB CDC serial driver.
3) In the device manager, look for the serial COM port number associated to the BCM-CW-E.



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.



PIC GAIN Control Window:

- 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: BVM input isolated

DB9 GAIN Control Window:

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

Save Configuration to BCM-CW-E:

- Stores the current BCM-CW-E settings in the BCM-CW-E microcontroller EPROM.

Load PIC Configuration: (automatically loaded at GUI start.)

- Load into GUI BCM-CW-E settings from BCM-CW-E microcontroller EPROM.

Delay Scan:

- When "Delay Scan" Toggle is up, GUI activates a delay scan in order to visualize the amplified BCM Input signal on BCM Output Graph.
- "Multiplier" value can be modified to speed up the scan. "Multiplier" = 1 will scan with the smallest possible step (10ps)
- A manual scan is possible using the "Delay cursor"

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 extract BCM-WC-E out of its station

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	\n\0 Ascii(10) Ascii(0)

Example: "D0:0123=00000005\n\0"

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

This table describes the command lines, 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:

<table>
<tr><th>Commands</th><th>Description</th><th>Command Frame (omitting termination)</th><th>Comments</th></tr>
<tr><td>D</td><td>Set on-board's digital delay line value (10bits)</td><td>D0:00000xxx</td><td>"xxx" must be an integer number in HEX format within the range "000" to "3FF"[3]</td></tr>
<tr><td>E</td><td>Save BCM-CW-E configuration to microcontroller's EEPROM</td><td>E0:00000001</td><td>Bit0 = 1</td></tr>
<tr><td>G</td><td>Set BCM-CW-E Gain Configuration</td><td>I0:0000000x</td><td>Single bits of the character "x" are used for configurations:

DB9/PIC Gain control :
Bit5 = 0 => SET Gain controlled by PIC
Bit5 = 1 => SET Gain controlled by Hardware (DB9)

The following Gain control bits are usable if Bit5 = 0 (Gain Controlled by PIC only)

Bit6 = 0 => PIC Gain Control A = 0
Bit6 = 1 => PIC Gain Control A = 1
Bit7 = 0 => PIC Gain Control B = 0
Bit7 = 1 => PIC Gain Control B = 1

<table>
<tr><th colspan="2">PIC Gain Control</th><th></th></tr>
<tr><th>Control A</th><th>Control B</th><th>BCM Input Gain</th></tr>
<tr><td>1</td><td>1</td><td>ISOLATED</td></tr>
<tr><td>0</td><td>1</td><td>0dB</td></tr>
<tr><td>1</td><td>0</td><td>20dB</td></tr>
<tr><td>0</td><td>0</td><td>40dB</td></tr>
</table>
</td></tr>
</table>

SY100EP195V delay line. Observe that SY100EP195V temperature dependence increases when the programmed delay increases

[3] More details on delay in ANNEX I

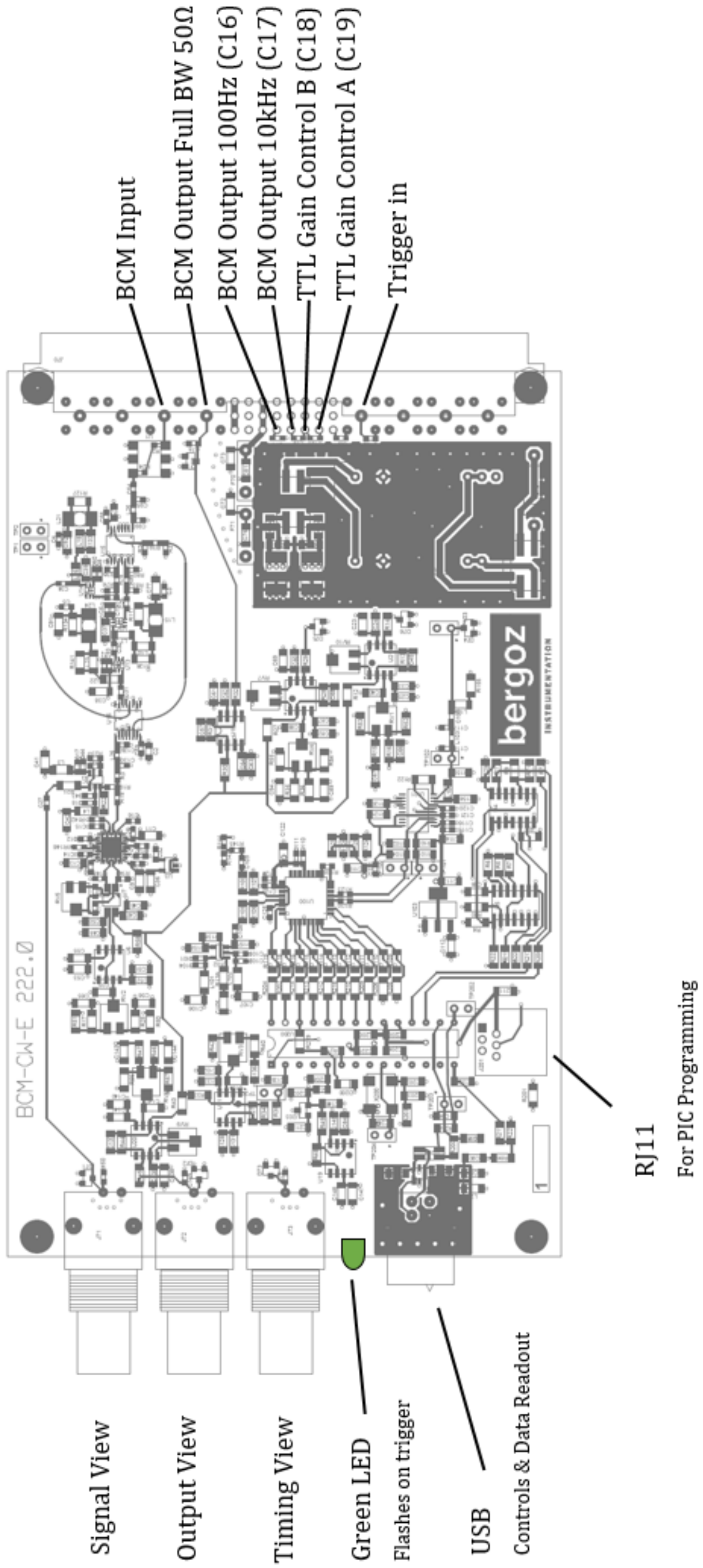
This table describes the read commands that can be sent by the host to the BCM-CW-E and the corresponding response frames returned by the BCM-CW-E back to the host.

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

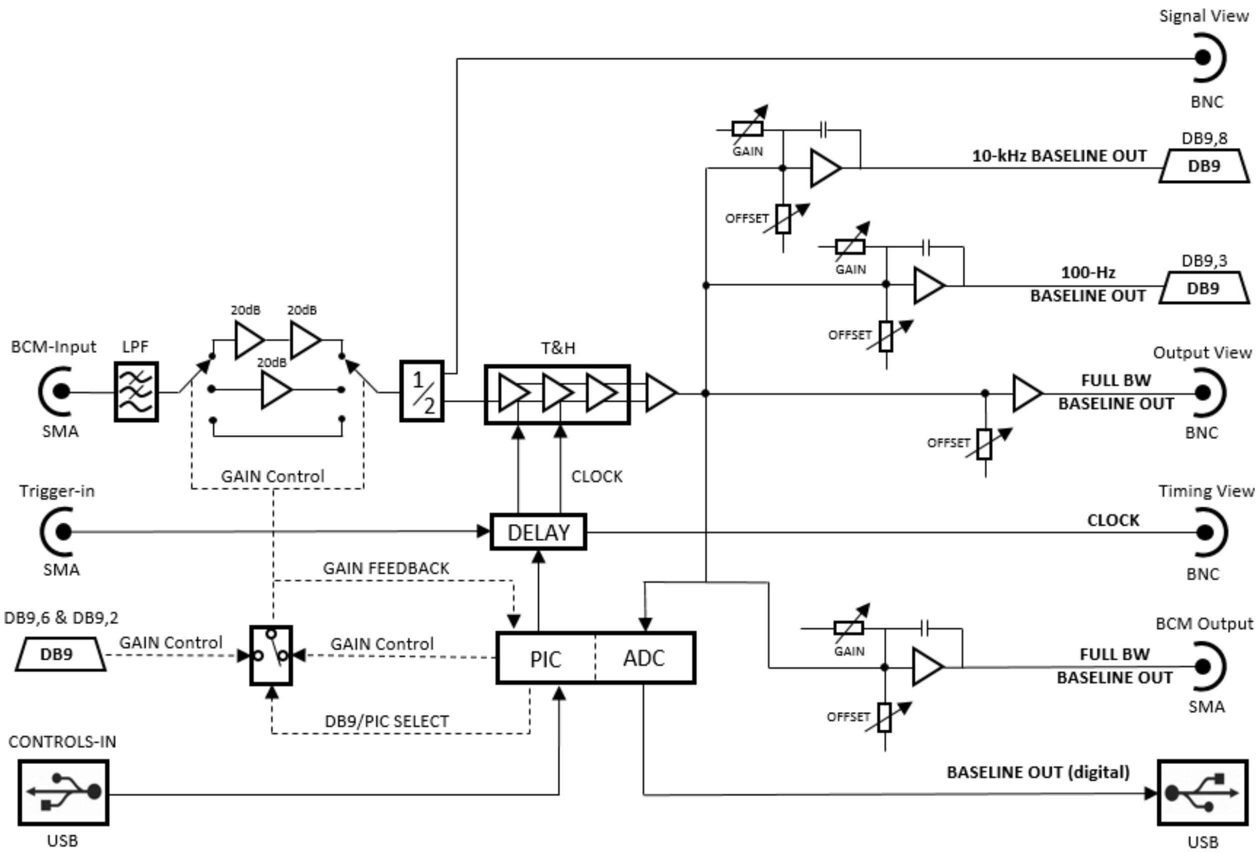
Command	Description	Command Frame (omitting termination)	Response Frame (omitting termination)	Comments
D	Read on-board's digital delay line value in nanoseconds	D0?	D0:zzzz=00000xxx	"xxx" is an integer number in HEX format within the range "000" to "3FF"
G	Read BCM-CW-E Gain configuration	G0?	G0:zzzz=000000x	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" and "FFFFFFFF"
X	Read input stage Gain set on board. If Gain Control has been set to be Hardware (DB9) Controlled. This Read function can return Hardware Gain configuration state.	X0?	X0:zzzz=000000xx	Bit0 = Control A (Hardware state) Bit 1= Control B (Hardware state)

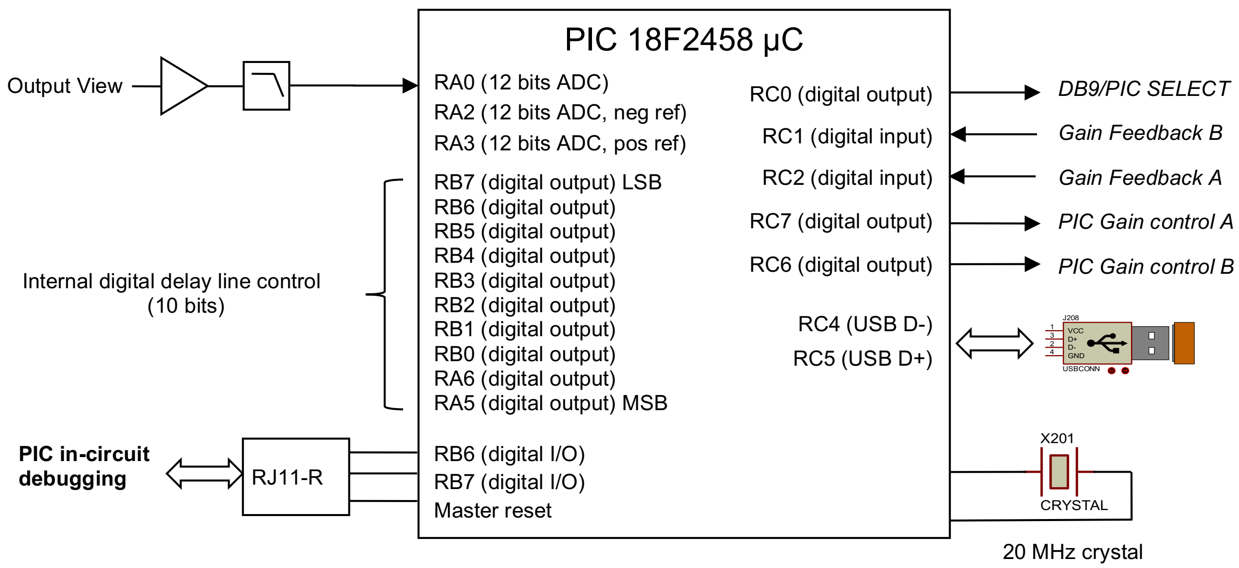
"zzzz" is a counter ranging from 0000 to FFFF which is incremented each time the BCM-CW-E tries to send data. After the counter reach FFFF it is reset to 0000.

BCM-CW-E INPUTS / OUTPUTS



ARCHITECTURE





GENERAL SPECIFICATIONS

Beam RF	60 MHz ... 500 MHz
Full scale ranges	Refer to "Measured ranges" table chapter[4]
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)
Temperature Dependence	~ -1400ppm/°C (Full scale) (Gain:20dB)
Bandwidth	~ 1MHz (-3dB)
Uncertainty	+/- 0.5mV
Output impedance	50Ω
Readout Impedance	50Ω
Maximum Current Source/Sink	+/-20mA
Response Time (@50%)	<1µs

Output View (Front panel BNC):

Output nominal	-4V … +4V proportional to full scale current
Output over range	-4.1V … +4.1V
Temperature Dependence	~ -1400ppm/°C (Full scale) (Gain:20dB)
Bandwidth	~ 1MHz (-3dB)
Uncertainty	+/- 2mV
Output impedance	100Ω
Readout impedance	High impedance
Max. Current Source/Sink	+/-10mA
Response Time (@50%)	<1µs

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

Nominal range	-4V … +4V proportional to full scale current
Output over range	-4.1V … +4.1V
Temperature Dependence	~ -1400ppm/°C (Full scale) (Gain:20dB)
Bandwidth	100Hz (-3dB)
Uncertainty	+/- 2mV
Output impedance	100Ω
Readout impedance	High impedance
Max. Current Source/Sink	+/-10mA

[4] 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
Temperature Dependence	~ -1400ppm/°C (Full scale) (Gain:20dB)
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 … -20dBm	20mVp-p … 60mVp-p
Amplitude Max	+4dBm	500mVp-p
Note	> -20dBm increases noise	> 60mV increases noise
Triggering Edge	Falling edge	Falling edge
Duty Cycle	-	20% … 80%
Input Impedance	50Ω	50Ω

BCM Input (Rear panel SMA):

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

Timing View (Front panel BNC):

Nominal output range	200mVp-p … 800mVp-p (into 50 Ω)
	400mVp-p … 1.6Vp-p (into High impedance)
Readout impedance	50Ω
Bandwidth	~ 270MHz (-3dB)
Triggering Edge	Rising edge

Signal View (Front panel BNC):

Nominal range	-0.5V… +0.5V (into 50 Ω)
	-1V … +1V (Into High impedance)
Output over range	-1.1V … +1.1V (into 50 Ω)
	-2.2v … +2.2v (into High impedance)
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 performance measured with CWCT 5.0, 2.5 and 1.25V/A.
Measurement ranges assuming a signal duty cycle of 50%:

		CWCT 5.0 V/A	CWCT 2.5 V/A	CWCT 1.25 V/A
0dB GAIN	Max	100mA	200mA	400mA
	Uncertainty	+/- 100µA	+/- 200µA	+/- 400µA
20dB GAIN	Max	20mA	40mA	80mA
	Uncertainty	+/- 10µA	+/- 20µA	+/- 40µA
40dB GAIN	Max	2mA	4mA	8mA
	Uncertainty	+/- 1µA	+/- 2µA	+/- 4µA

Measurement ranges assuming a signal duty cycle of 33%:

		CWCT 5.0 V/A	CWCT 2.5 V/A	CWCT 1.25 V/A
0dB GAIN	Max	66.6 mA	133,3mA	266.6mA
	Uncertainty	+/- 100µA	+/- 200µA	+/- 400µA
20dB GAIN	Max	10mA	20mA	40mA
	Uncertainty	+/- 10µA	+/- 20µA	+/- 40µA
40dB GAIN	Max	1mA	2mA	4mA
	Uncertainty	+/- 1µA	+/- 2µA	+/- 4µA

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 consomption	+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

		DIN41612M BCM-CW-E module rear connector	DB9 female connector on BCM-RFC rear panel	RF-Chassis Rear SMA connectors	BCM-CW-E Front panel BNC connectors
INPUT SIGNALS					
BCM-CW-E Input 50 Ω (to connect to CWCT)	BCM Input	B8[5]		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[5]		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[5]		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		

[5] 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 much 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 the installed on the cable.

This is imperative to assure EMI rejection for system performance.

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 Yellow Books).
- 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

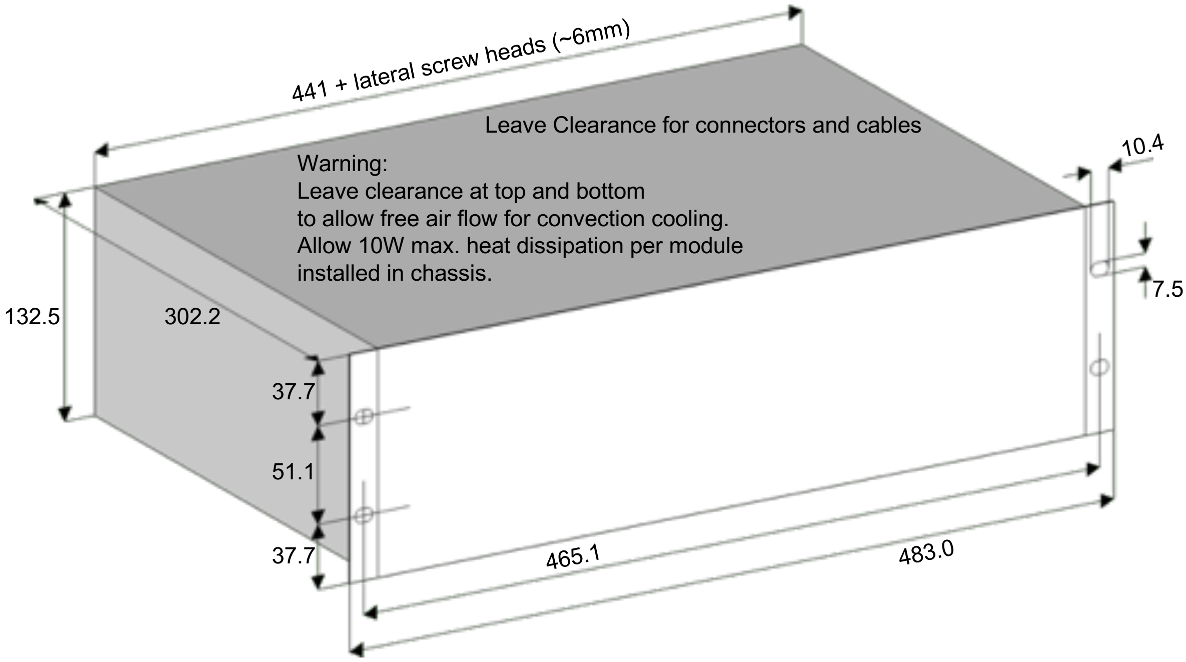
Schroff reference: Europac Lab HF/RF #20845-283

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



Card Extender: ref. BCM-XTD

The card extender allows access to the BCM-CW-E on-board RJ11-R for Microchip in-circuit debugger while the BCM-CW-E module is connected to the chassis.

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, January 2018

ANNEX I

MICREL®

3.3V/5V 2.5GHz PROGRAMMABLE DELAY

ECL Pro®
SY100EP195V

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.

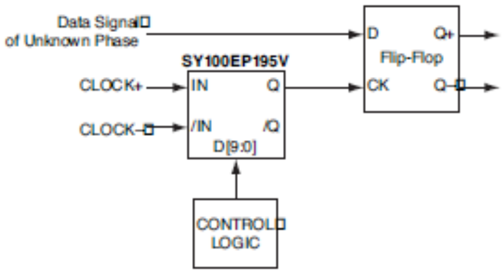
APPLICATIONS

- Clock de-skewing
- Timing adjustment
- Aperture centering

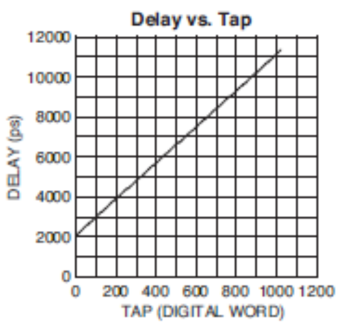
CROSS REFERENCE TABLE

Micrel Semiconductor	ON Semiconductor
SY100EP195VTI	MC100EP195FA
SY100EP195VTITR	MC100EP195FAR2

TYPICAL APPLICATIONS CIRCUIT



TYPICAL PERFORMANCE



ECL Pro is a registered trademark of Micrel, Inc.

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)

		T_A = –40°C			T_A = +25°C			T_A = +85°C			
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
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	ps_{RMS}
V_{PP}	Input Voltage Swing (Differential)	150	800	1200	150	800	1200	150	800	1200	mV
t_r t_f	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.