USER MANUAL

LR BPM

Log – ratio

Beam Position Monitor

Rev. 4.0

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More than 40 years of experience recognized in the world of particle accelerators

Record of updates

Version	Date	Updates performed
2.2.1	04/2008	CONNECTORS PINS ALLOCATION Rev. 2.1 Optional output signals: LogA, LogB, LogC and LogD pin assignment on DIN41612M LR-BPM module rear connector has been corrected to resp. b31*, b223, b28* and B25*. Note to users of BPM-RFC chassis with BPM-RFC/ABCD option: The locations of chassis rear panel SMA output connectors LogA, LogB, LogC and LogD are unchanged.
3.0	01/2020	Review of the full manual. Obsoletes all previous versions
3.1	11/2020	Update of the Table of Contents Correction of the chapter “Agreement on Axis & Signs”
3.2	06/2021	Modification of the power supply references
4.0	07/2024	Manual layout update

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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. 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, disassembly, neglect, use of faulty part, accident or abnormal conditions, repair made by the customer, 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: The purchaser/customer must ask for a RMA (Return Material Authorization) number to Bergoz Instrumentation or its local distributor before return of goods. Bergoz Instrumentation will repair or replace any product under warranty at no charge.

For products in need of repair after the warranty period, Bergoz Instrumentation will assess the technical issue and send a quote to the purchaser/customer. The purchaser/customer must provide a purchase order before repairs can be initiated. Bergoz Instrumentation can issue fixed price quotations for most repairs.

RETURN PROCEDURE

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

The shipment of a product under warranty or out of warranty back to the factory is paid by the user/customer, including the customs fees. The return of this repaired product under warranty back to the customer is paid by Bergoz Instrumentation.

Return of product out of warranty should be made prepaid or will be invoiced. Bergoz Instrumentation will not accept freight-collect shipments. Shipments should be made via UPS, FedEx or DHL. Within Europe, the transportation services offered by the national Post Offices 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 shall be used outside the U.S. and Canada, fuse configuration must be modified so that both Phase and Neutral will 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.

BEAM POSITION MONITOR SYSTEM

This manual applies to the Log-ratio BPM only: LR-BPM
"MX-BPM", "S-BPM" and "BB-BPM" are described in other manuals.

The Log-ratio BPM system includes:

Description	*Order code*
Log-ratio BPM electronics module	LR-BPM-XXXMHz
Sample & Hold on X and Y, option	LR-BPM-SH
Beam Trigger, option	LR-BPM-TRG
Sum of logs, option	LR-BPM-SUM

The options are factory-installed on the LR-BPM electronics module.

Accessory:
19" chassis with power supply BPM-RFC/X, X = BPM stations number

Check the power supply voltage, that it corresponds to your mains voltage.
Check the fuse configuration, that it corresponds to your national regulations.

The 19" BPM-RFC chassis fuse compartment is configured at the time of shipment according to its destination:

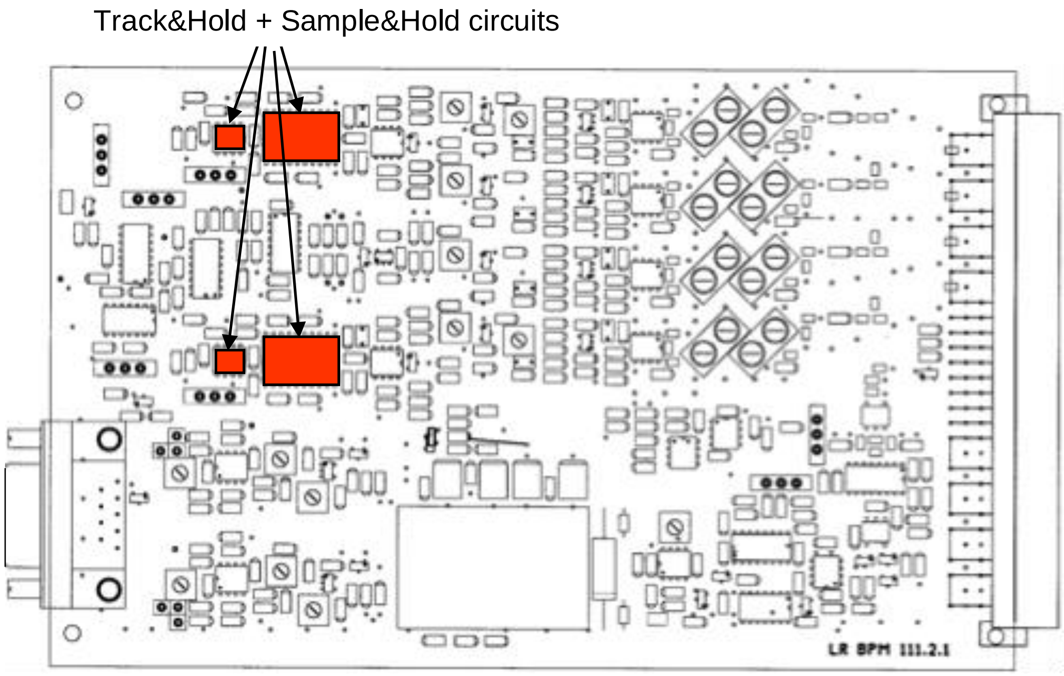
- North America: mains ground wire unfused.
- All other destinations: both mains wires are fused.
  To verify which fuse configuration is installed on your chassis, pull out the removable fuse block, using a small screwdriver.
- The unfused ground configuration has a shorting bar and a 2A 6x32 fuse.
- The configuration with both AC lines fused is equipped with two 2A 5x20 fuses.
  To change this configuration, unscrew the fuse holder off the fuse block, flip the holder over and screw it back onto the fuse block. Insert the following fuses:
- For unfused ground configuration: one 2A 6x32 fast fuse.
- For both AC lines fused configuration: two 2A 5x20 fast fuses.

Determine which LR-BPM model you received

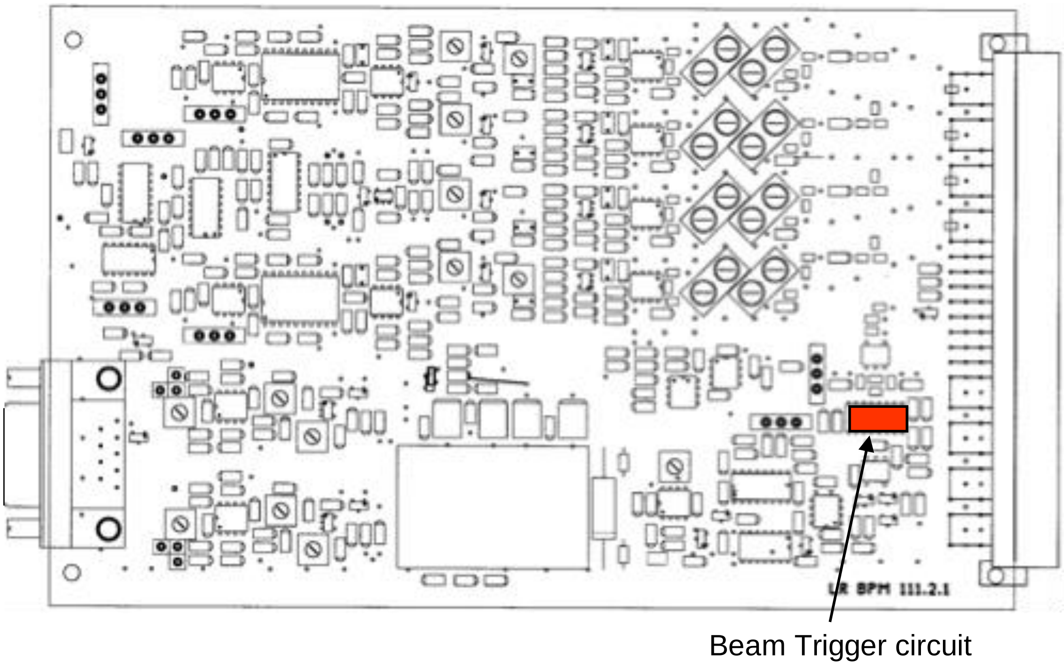
LR-BPM version-1 have serial numbers < #955. They are described in another manual.
If you have a Version-1 unit, please ask Bergoz Instrumentation or your distributor to send the LR-BPM User's Manual version 1.x.

LR-BPM version-2.0 have serial numbers #956 ≤ SN ≤ #1074
The circuit revision number 111.2.0 is engraved on the printed circuit board "solder side".
LR-BPM version-2.0 are the object of this User's Manual.

LR-BPM version-2.1 have serial numbers #1092 ≤ SN ≤ #xxx
The circuit revision number 111.2.1 is engraved on the printed circuit board.
LR-BPM version-2.1 with Sample & Hold option LR-BPM-SH can be recognized by:
The printed circuit is equipped with Track&Hold + Sample&Hold circuits.



LR-BPM version-2.1 with Beam Trigger option LR-BPM-TRG can be recognized by:
The printed circuit board is equipped with a log amplifier limiter circuit:



MODES OF OPERATION FOR VARIOUS BEAMS

LR-BPM can be equipped with many options, then further configured by the user to support many modes of operation:

Sample & Hold (S&H) Mode

Note: Requires Sample&Hold option LR-BPM-SH to be mounted on the printed circuit board.

Processing time	~450 ns
Hold time	Up to 100 ms
ADC measurement time	At maximum repetition rate, at least 100 ns “good” signal
Repetition rate	Up to 2 MHz

Indicated for: Linacs: single bunch, bunch trains, prebunched S-band/X-band
Transfer lines
Synchrotron first turn
Synchrotron single bunch turn-by-turn
Synchrotron multi-single bunch turn-by-turn, using trigger gate.

Refer to “Sample & Hold Mode” for switch settings

Track & Hold (T&H) Mode

Note: Requires Sample&Hold option LR-BPM-SH to be mounted on the printed circuit board.

Processing time	~110 ns
Hold time	~70 ns
ADC measurement time	At maximum repetition rate, at least 50 ns “good” signal
Repetition rate	Up to 5 MHz

Indicated for: Synchrotron 2 MHz < f_{rev} < 5 MHz, single bunch turn-by-turn
Synchrotron multi-single bunch turn-by-turn, using trigger gate.

Refer to Track & Hold Mode” for switch settings

Track Continuous (T) Mode

Note: Does not require Sample & Hold option. Does not require Built-in Beam Trigger option

Output bandwidth 5 MHz

Indicated for: CW beams in general:

- Linacs and synchrotrons with bunch repetition rate up to 500 MHz
- Betatron oscillation monitoring in boosters and storage rings
- L-band, S-band, X-band linacs prebunched up to 500 MHz
- Smaller-size ion and proton synchrotrons with f_{rev} > 5 MHz.

Refer to “Track-Continuous Mode” for switch settings.

In Sample&Hold (S&H) and Track&Hold (T&H) modes, LR-BPM must be triggered.

Triggering can be provided:

a) by the built-in Beam Trigger, if installed on LR-BPM (order code LR-BPM-TRG). To use the built-in Beam Trigger, it must be enabled by its switch. See TRG switch below.

b) by an external signal applied to TG.IN.AUX input. To use the external trigger, the built-in trigger –if installed– must be disabled. See TRG switch below.

OPTIONS

In addition to the Sample & Hold option described in the preceding chapter, other options are available:

Built-in Beam Trigger “LR-BPM-TRG” option

Note: Requires Built-in Beam Trigger option LR-BPM-TRG to be mounted on the printed circuit board.

Particle polarity	LR-BPM version 2.1 operates with positive and negative particle polarity
Minimum detected charge	100 pC bunch seen by four pickups of 5 pf capacitance and width = 1/8 of circumference.
Maximum repetition rate	5 MHz.

Sum of logs Output “LR-BPM-SUM” option

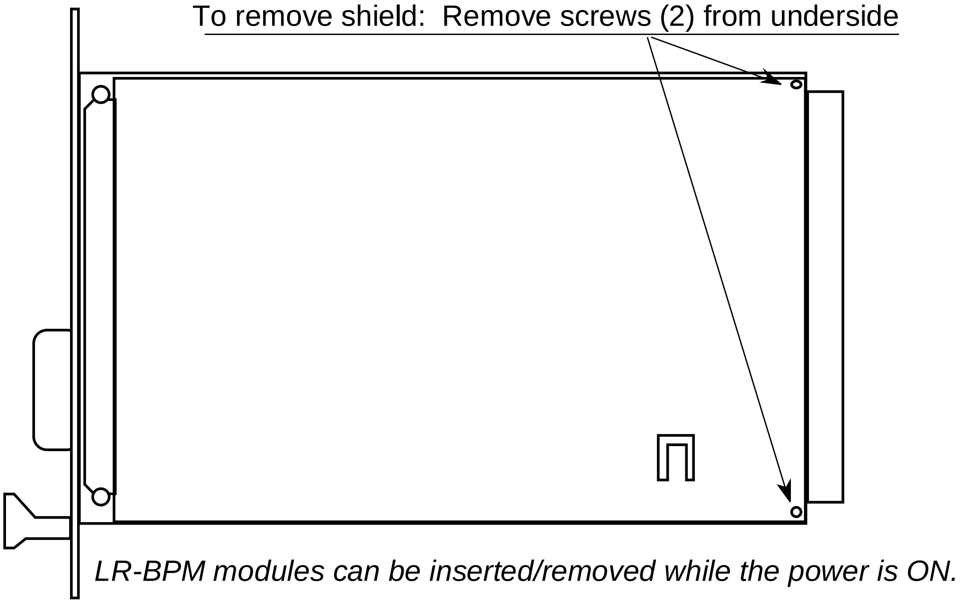
Note: Requires Sum-of-Logs option LR-BPM-SUM to be mounted on the printed circuit board.

Value	SUM = Log(A) + Log(B) + Log(C) + Log(D)
Bandwidth	5 MHz

See typical Log(A) output from a single bunch on preceding page timing diagram

ACCESS to STRAPS and SWITCHES

To access switches or straps, remove the module shield:



The LR-BPM module is equipped with many on-board potentiometers to adjust the log amplifiers gain, slope and intercept point. They require precise instruments, tools and procedures for their adjustment.

LR-BPM PRINCIPLE OF OPERATION

The signals from the pickup electrodes are processed simultaneously thru four independent channels. Each channel consists of an input band-pass filter, followed by an amplification chain with logarithmic response.
When a single short pulse is applied to the band-pass filter, it will oscillate at its own resonant frequency for about 250 ns, allowing enough time for the logarithmic amplifier to detect the log of its envelope.

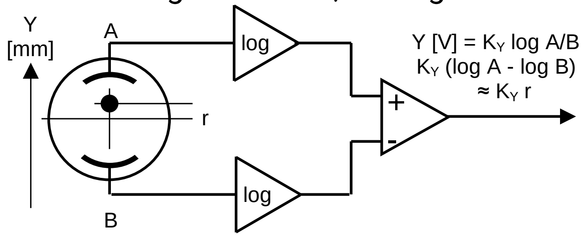
Each amplifying chain produces a signal which peak amplitude is proportional to the log of the input signal, be it a single pulse, a pulse train, or a continuous wave.

Log signals from opposite pickup electrodes are deducted from one another to obtain Log(A) - Log(C) = Log(A/C) which is said to be a very faithful representation of beam displacement between two pickup electrodes.

If the pickup electrodes are placed along the axes in which the beam displacement is to be measured, the displacement $X = K_X$ Log(A/C), directly. The K_X gain is obtained by an amplifier with adjustable gain. The same goes for the Y axis.

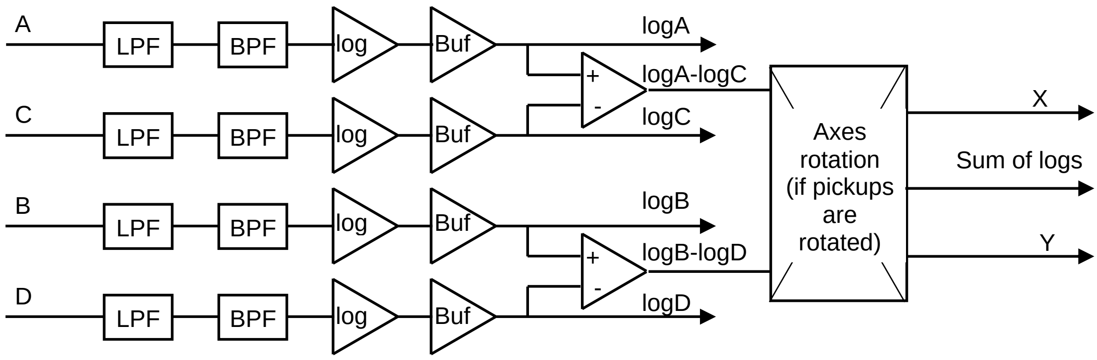
If the pickup electrodes are placed along axes rotated as compared to the beam position measurement axes, the A-C and B-D axes must be rotated to obtain the beam displacement values along X and Y. The rotation is done wideband with >5 MHz response applying the algorithm hereafter:

Schematic representation of the log-ratio BPM, an original concept of Robert E. Shafer:



Position measured by this method is more linear, over a wider range, than difference-over-sum.

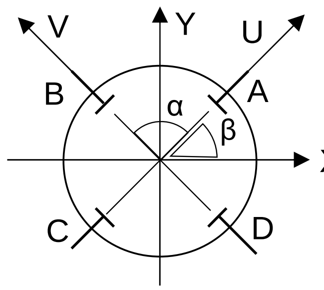
BLOCK DIAGRAM



AGREEMENT ON AXES & SIGNS

X, Y: User's orthogonal axes
U, V: LR-BPM pickup axes AC and BD
K_X, K_Y: gain obtained by an amplifier with adjustable gain

ROTATED PICKUPS

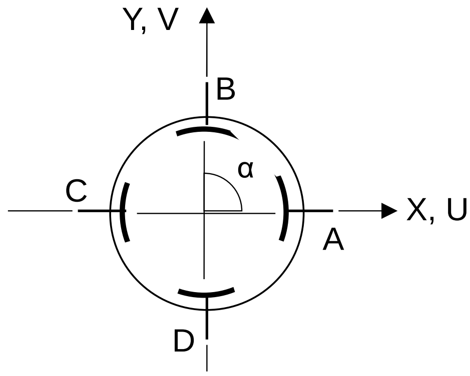


α = 90°
β ≠ 0
Note: α may be ≠ 90°. S-BPM is factory-set for equal X and Y gains, i.e., α= 90°

U = Log(A/C)
V = Log(B/D)
Note: U and V are signals of positive polarity

$X = K_x \cdot (U \cdot \cos\beta - V \cdot \sin\beta)$
$Y = K_y \cdot (U \cdot \sin\beta + V \cdot \cos\beta)$

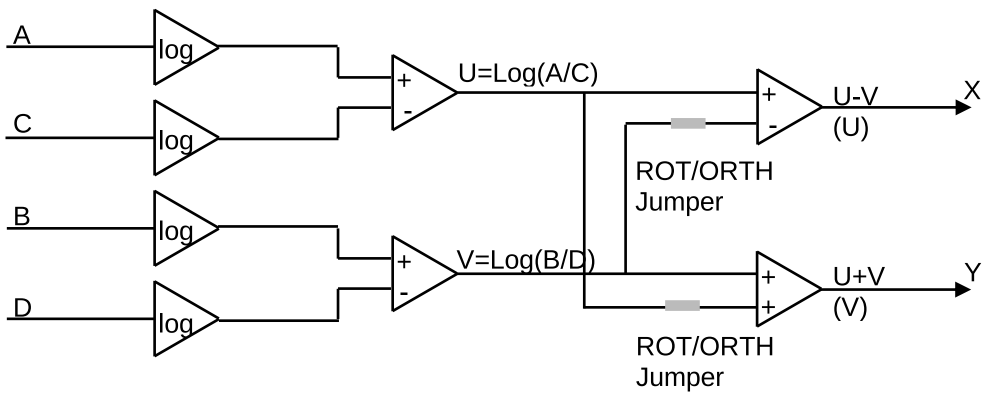
ORTHOGONAL PICKUPS



α = 90°
β = 0

U = Log(A/C)
V = Log(B/D)
Note: U and V are signals of positive polarity

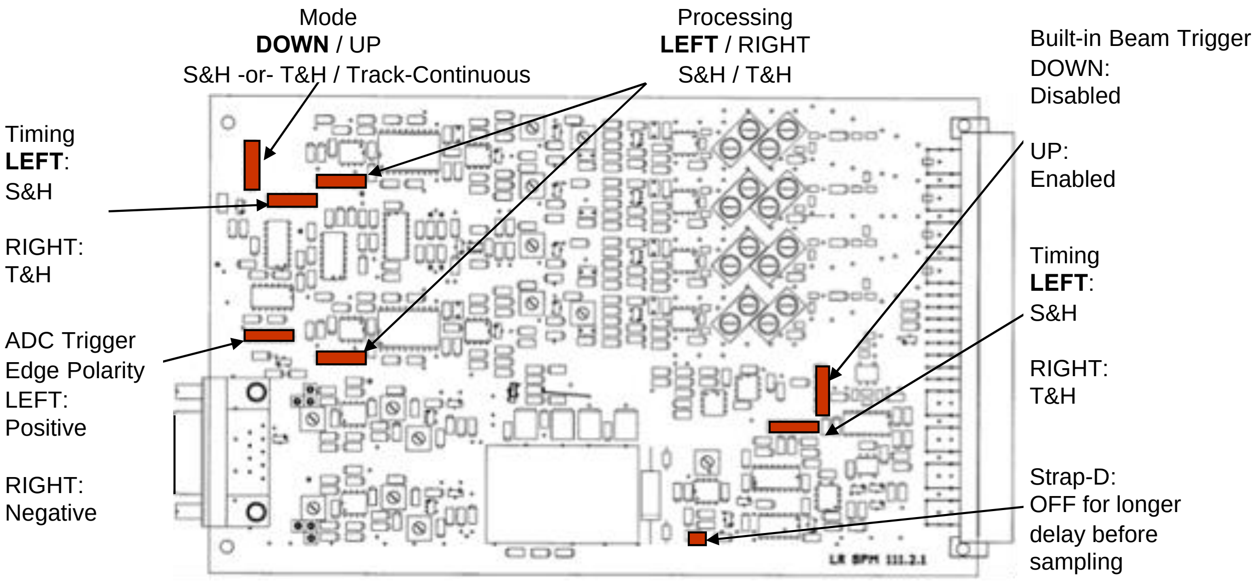
$X = K_x \cdot U$
$Y = K_y \cdot V$



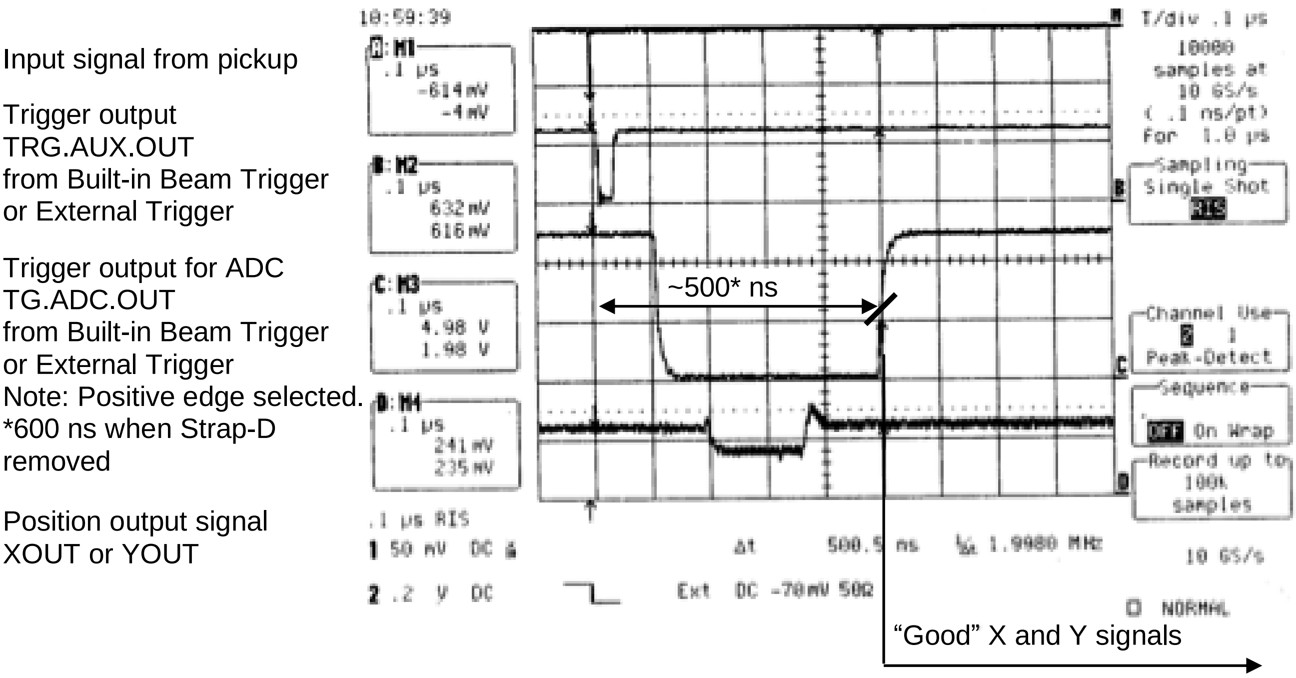
For details on pickup sensitivity and log-ratio, consult:
Log-ratio Signal-Processing Technique for Beam Position Monitors, Robert E. Shafer, Proceedings of the Fourth Accelerator Instrumentation Workshop, Berkeley 1992.
AIP Conf. proceedings No. 281, pages 120-128.

SAMPLE & HOLD MODE

Set switches to:
Mode: Sample&Hold (DOWN)
Processing: Sample&Hold (LEFT position)
Timing: Sample&Hold (LEFT position)
Built-in Beam Trigger: As desired
ADC Trigger Output Edge: As desired



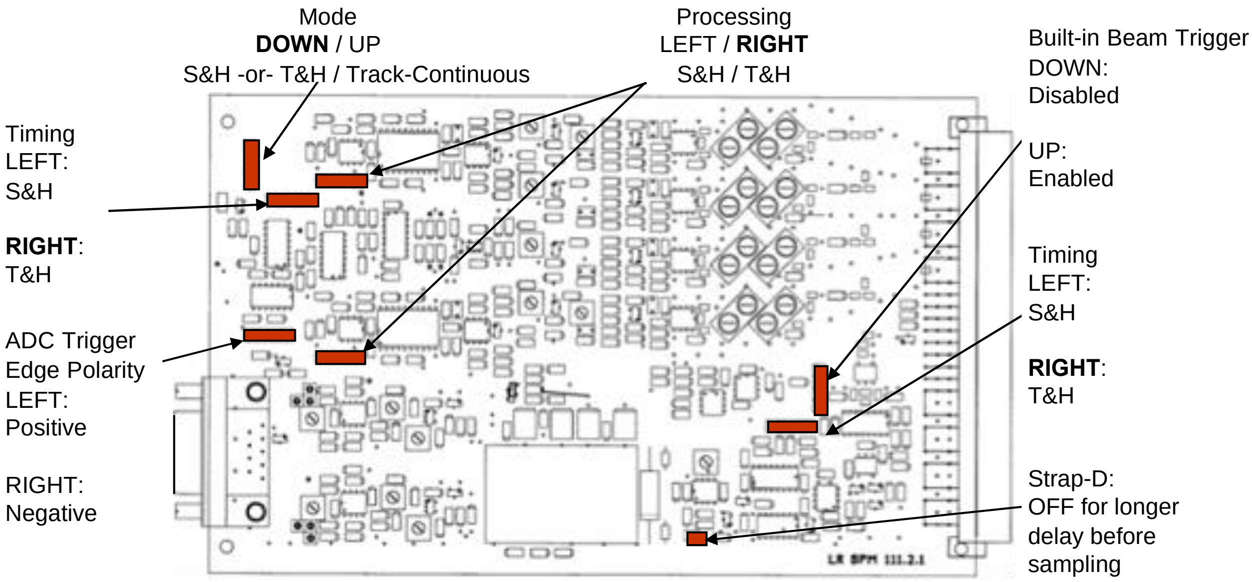
Signal timing in Sample & Hold mode



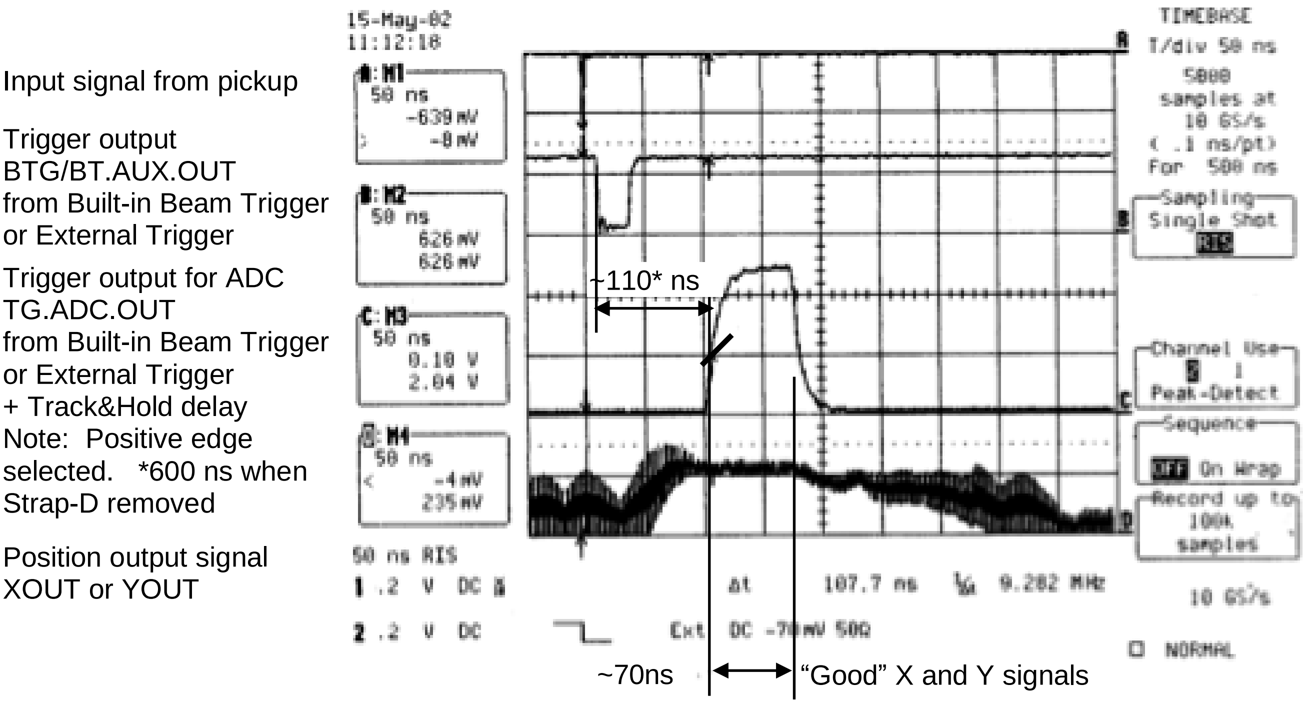
TRACK & HOLD MODE

Set switches to:

- Mode: Track&Hold (DOWN)
- Processing: Track&Hold (RIGHT position)
- Timing: Track&Hold (RIGHT position)
- Built-in Beam Trigger: As desired
- ADC Trigger Output Edge: As desired



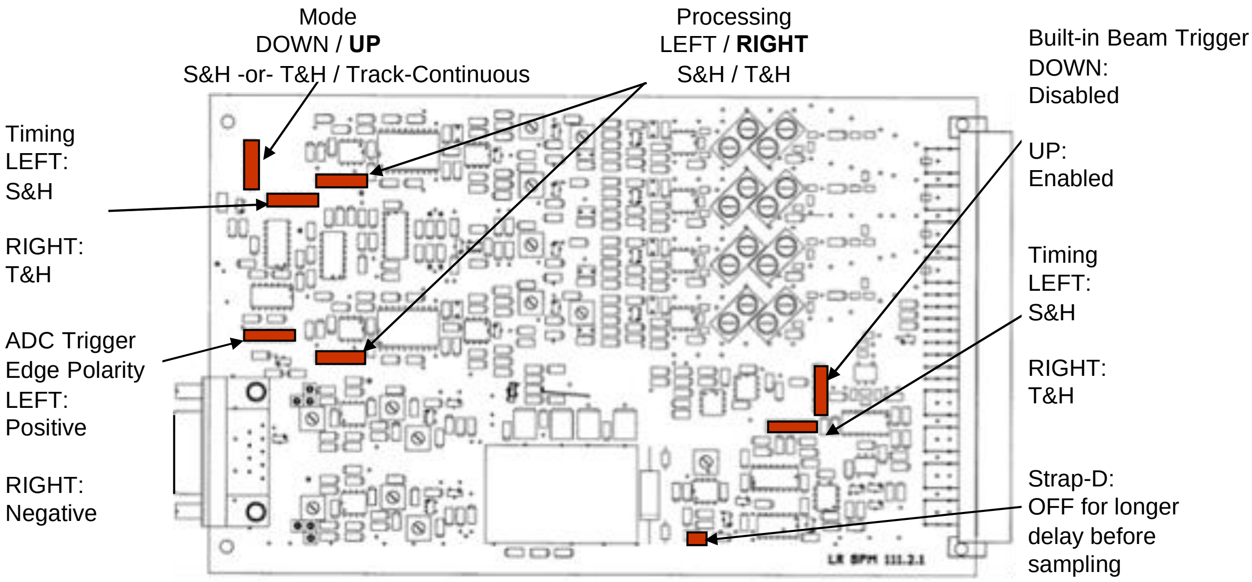
Signal timing in Track & Hold mode



TRACK-CONTINUOUS MODE

Set switches to:

Mode: Track-Continuous (UP)
Processing: Track&Hold (RIGHT position)
Timing: Choose suitable position according to ADC
Built-in Beam Trigger as desired
ADC Trigger Output Edge as desired



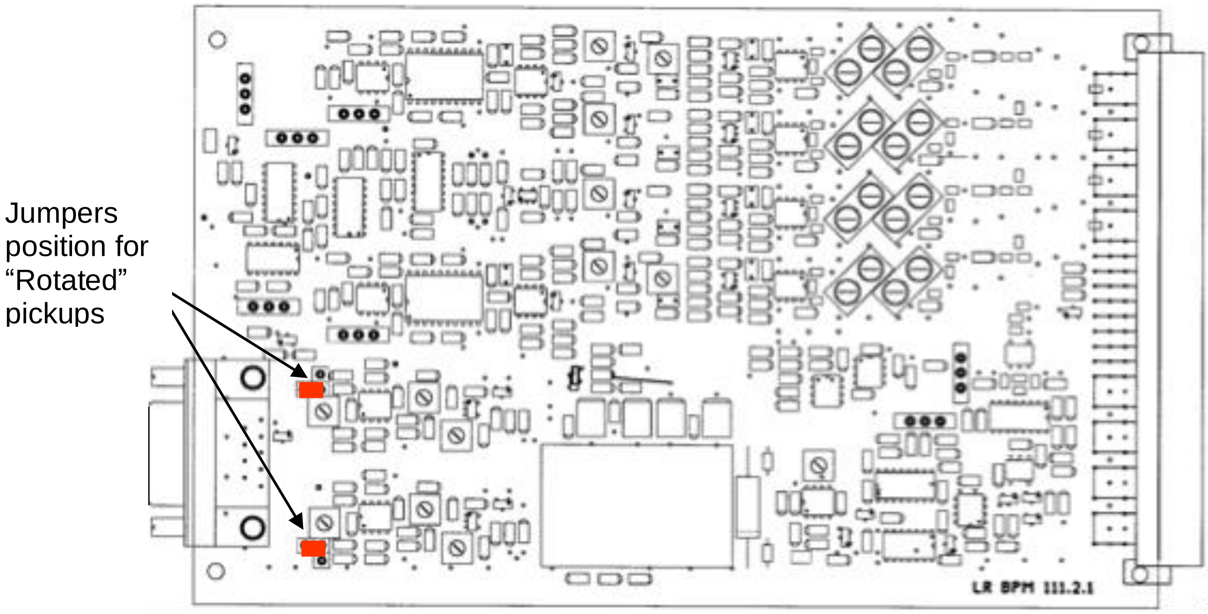
Note: Built-in Beam Trigger (Option LR-BPM-TRG) will not operate above 5 MHz bunch repetition rate

Output signals XOUT and YOUT track the position given by A, B, C and D inputs with 5 MHz bandwidth.

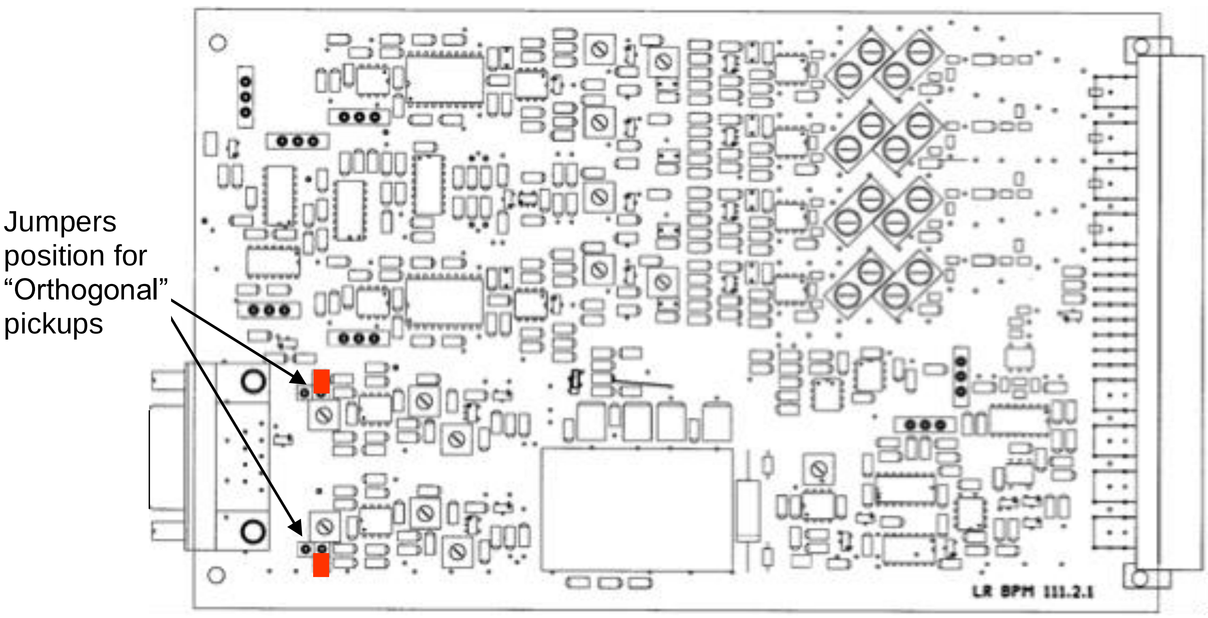
CHANGING PICKUP CONFIGURATION

The pickup configuration is set with two jumpers.
To change the configuration from “Rotated” to “Orthogonal” or vice versa, change the jumper position:

Rotated pickups, position of jumpers



Orthogonal pickups, position of jumpers



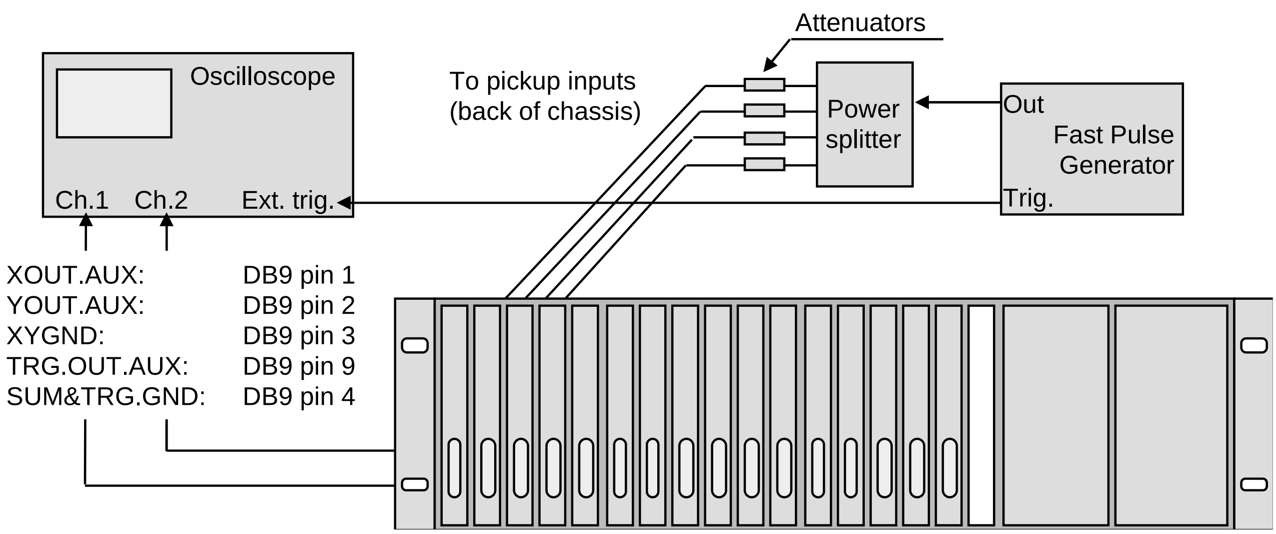
QUICK CHECK: LR-BPM IN SAMPLE&HOLD MODE

Note: This Quick Check works only if Sample & Hold LR-BPM-SH option is installed

Unless otherwise specified on the Certificate of Calibration, LR-BPM with Sample&Hold option has following ex-factory settings:

- Rotated pickups
- Built-in Beam Trigger
- Mode, Timing and Processing: S&H
- Built-in trigger: Enabled
- ADC Trigger output: Positive edge

Setup: to check immediately that your LR-BPM system is working.



Attach the equipment together as shown above.

Set the fast pulse generator to:

- Output voltage: 50V (in 50-ohm)
- Pulse polarity: negative
- Pulse width ≤ 1 ns fwhm
- Pulse repetition: slow (in the Hz to kHz range)

Note: Signals applied to LR-BPM inputs will be attenuated by the 4-way splitter:

- Transformer-type 4-way splitters typically attenuate by 7dB,
- 4-way resistive splitters or cascaded 2-way splitters attenuate by 12dB.

This 50V pulse, after splitting in a transformer-type 4-way splitter (-7 dB) is about equivalent to a 10-nC bunch seen by four pickups of 5 pf capacitance and width = 1/8 of circumference.

Use 4 similar attenuators, each 3 dB. The same test can be done with 5 and 10 dB.
Note: Attenuators are seldom more precise than ±0.1 dB. This will be reflected upon the LR-BPM X and Y zero readings.

Connect to Test Kit or 19” BPM-RFC chassis to AC mains.

Auxiliary trigger output

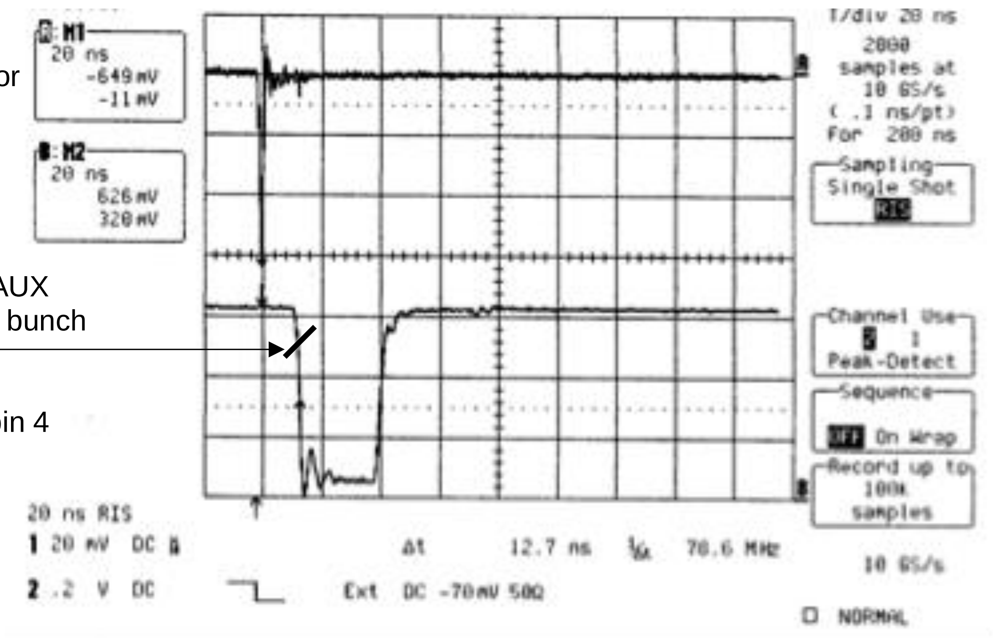
Observe the Auxiliary trigger from LR-BPM. This trigger is used for oscilloscope triggering.

Input signal from Fast Pulse generator (50 Ω):

Output DB9 pin 9 TRG.OUT.AUX (1-MΩ):

Trigger TRG.OUT.AUX comes ~13 ns after bunch

Ground from DB9 pin 4



ADC Trigger output and Auxiliary X or Y outputs

Observe ADC Trigger output, available from the DB15 connector pin 5, either at side of BPM-KIT or at rear of BPM/RFC chassis.

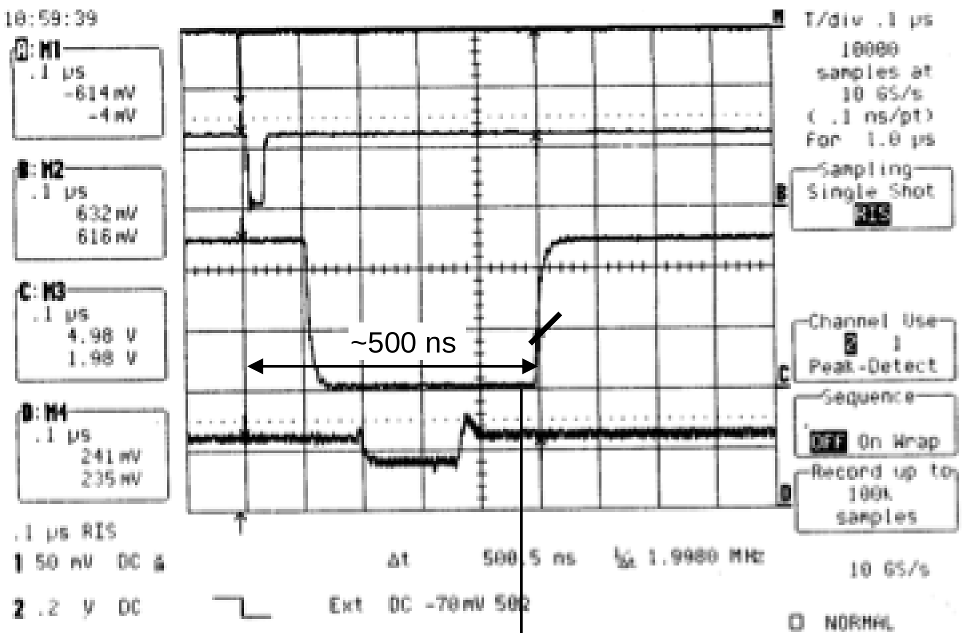
Input signal from Fast Pulse generator (50 Ω)

Output DB9 pin 9 TRG.OUT.AUX (1 MΩ)

Output DB15 pin 5 TG.ADC.OUT (1 MΩ)

Output DB9 pin 1 XOUT.AUX (1 MΩ)

GND from DB9 pin 4



"Good" X and Y signals

Good output signal on Auxiliary X output X.OUT.AUX DB9 pin 1, starts with TG.ADC.OUT downswing, ~500 ns after beam bunch. Output signal is held more than 100 milliseconds

Note: Your ADC can be triggered from DB15 pin 5 output signal TRG.ADC.OUT:

- First edge is ~120 ns after the beam bunch
- Second edge is ~500 ns after the beam bunch.

Polarity of edge is determined by ADC Trigger Edge Polarity switch.

Auxiliary outputs X and Y are available on DB9 pin 1 and pin 2 respectively.

XOUT and YOUT Zero Offsets

If the signals applied to all four LR-BPM inputs were exactly equal, and if the LR-BPM module were perfect, the values of X and Y would be exactly 0 Volt.
This is generally not the case, X and Y will be many tens or even hundreds of millivolts off.

You can determine how much of this offset is caused by attenuator inequality:
Swap the attenuators A and C, then B and D and observe the offset change.

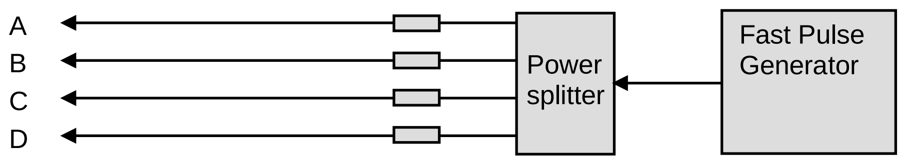
You can determine how much of this offset is caused by power splitter imbalance:
Instead of connecting attenuator A to power splitter output 1, connect it to output 3 and connect attenuator C to output 1.
Do the same for attenuators B and D with power splitter outputs 2 and 4.

Simulating beam position changes

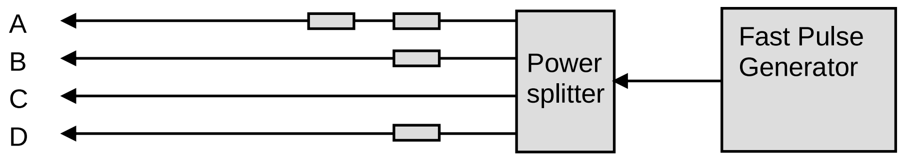
To simulate beam position changes, the input signal power is changed by 6 dB, 10 dB and 14 dB, hence simulating position changes up to 1/3 of vacuum chamber radius.

The pulse generator output amplitude should be in the range 5V...50V
The LR-BPM on-center sensitivity is factory-set to 55.5 mV per dB of signal difference between opposite pickups. For pickups with small angle (e.g. buttons), 6 dB corresponds to beam displacement equal to 1/6 of vacuum chamber radius. As the beam goes far off center, this sensitivity becomes lower due to the algorithm X = Log (A/C). Please consider that the pickup sensitivity becomes higher as the beam goes off center, and one non-linearity tends to compensate the other.

Before simulating a beam displacement, start by noting the X and Y zero offsets, using four equal attenuators:



Then simulate the displacement by removing an attenuator from one input and inserting it in the opposite input: A <=> C, and B <=> D.
Example:



Attenuator C is removed from input C, and added to input A, thus simulating a displacement of the beam towards C (stronger signal on C pickup).

LR-BPM modules are factory preset:

- For orthogonally placed pickups: up, down, left and right
  or,
- For rotated pickups: upper-right, upper-left, lower-left and lower-right.

The combinations on the following table can be tried, yielding the X and Y values listed.

Note: These are displacements. Take into consideration the zero offsets due to power splitter imbalance and attenuators inequality.

Table of X/Y output voltage vs. input amplitude

Input	Attenuators	Equivalent displacement	Rotated pickups	Orthogonal pickups
A	3 + 3	1/6 of radius towards C		
B	3		X = -0.245 V	X = -0.347 V
C	0		Y = -0.245 V	Y = 0 V
D	3	(button pickups << chamber diameter)		
A	3 + 3	1/6 of radius towards C		
B	3 + 3	1/6 of radius towards D	X = 0 V	X = -0.347 V
C	0		Y = -0.490 V	Y = -0.347 V
D	0	(button pickups << chamber diameter)		
A	5 + 5	1/4 of radius towards C		
B	5		X = -0.407 V	X = -0.576 V
C	0		Y = -0.407 V	Y = 0 V
D	5	(button pickups << chamber diameter)		
A	5 + 5			
B	5 + 5		X = 0 V	X = -0.576 V
C	0		Y = -0.814 V	Y = -0.576 V
D	0	(button pickups << chamber diameter)		
A	10 + 7	1/3 of radius towards C		
B	10		X = -0.570 V	X = -0.806 V
C	3		Y = -0.570 V	Y = 0 V
D	10	(button pickups << chamber diameter)		

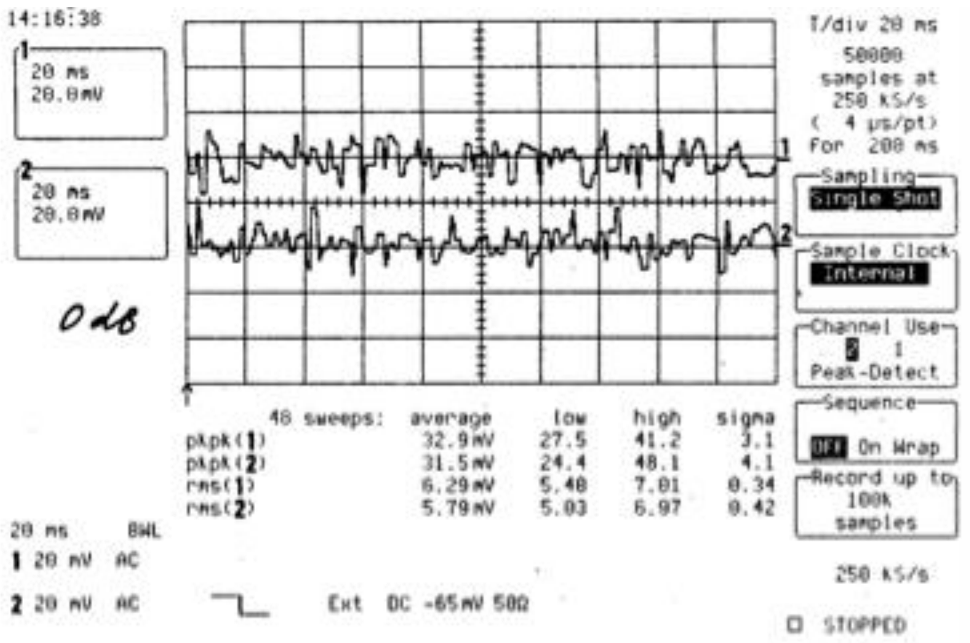
Note: These are displacements. Take into consideration the zero offsets due to power splitter imbalance and attenuators inequality.

Noise measurement

X and Y outputs exhibit noise. The following test gives a feel of the noise, without the need for a sophisticated data acquisition system.
An oscilloscope takes a single sweep of Xout and Yout. Its timebase is set to display –in a single sweep– the outputs corresponding to ~200 input pulses:

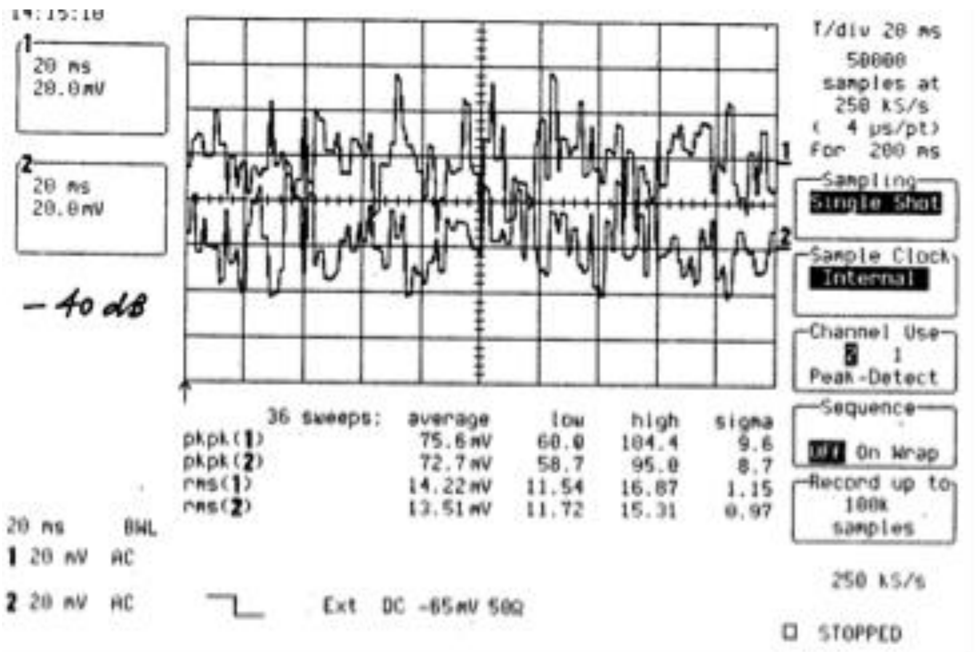
X and Y outputs corresponding to a bunch **~10nC** "seen" by four pickups, ea. 5 pf capacitance and width = 1/8 of circumference.

Pulse Generator: 50V - 0.75ns



X and Y outputs corresponding to a bunch **~100pC** "seen" by four pickups, ea. 5 pf capacitance and width = 1/8 of circumference.

Pulse Generator: 0.05V - 0.75ns



QUICK CHECK: LR-BPM IN TRACK&HOLD MODE

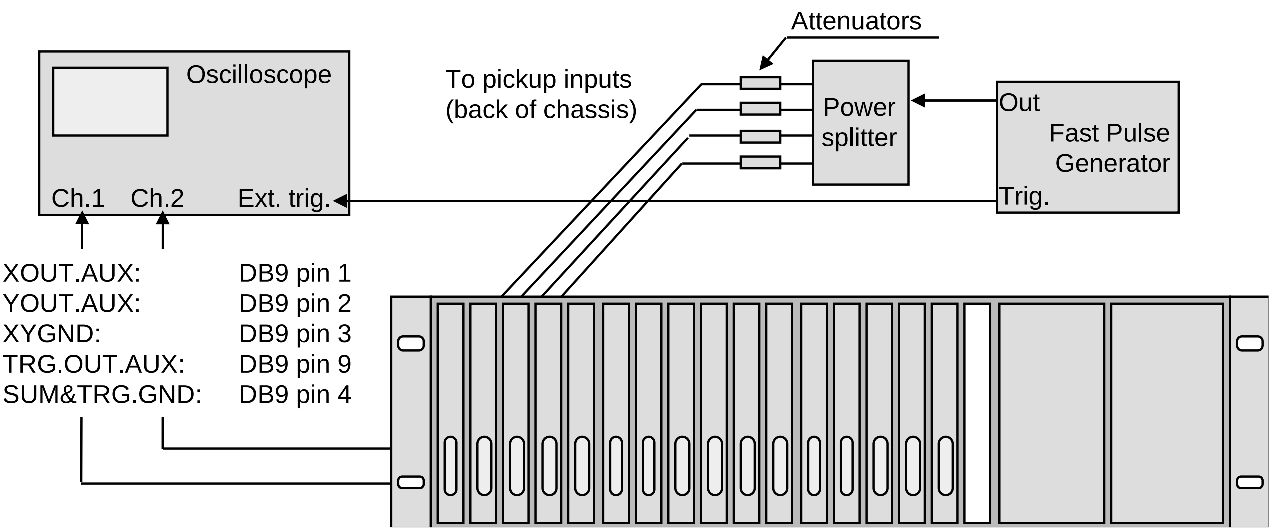
Note: This Quick Check works only if LR-BPM-SH (Sample & Hold) option is installed.

LR-BPM ordered specifically for Track&Hold operation has following ex-factory settings:

–Unless otherwise specified–

- Rotated pickups
- Built-in Beam Trigger
- Mode, Timing and Processing: Track&Hold
- Built-in trigger: Enabled
- ADC Trigger output: Positive edge

Setup: to check immediately that your LR-BPM system is working.



Attach the equipment together as shown above. Set the fast pulse generator to:

- Output voltage: 50V (in 50-ohm)
- Pulse polarity: negative
- Pulse width ≤ 1 ns fwhm
- Pulse repetition: slow (in the Hz to kHz range).

Note: Signals applied to LR-BPM inputs will be attenuated by the 4-way splitter:

- Transformer-type 4-way splitters typically attenuate by 7dB,
- 4-way resistive splitters or cascaded 2-way splitters attenuate by 12dB.

This 50V pulse, after splitting in a transformer-type 4-way splitter (-7 dB) is about equivalent to a 10-nC bunch seen by four pickups of 5 pf capacitance and width = 1/8 of circumference.

Use 4 similar attenuators, each 3 dB. The same test can be done with 5 and 10 dB.
Note: Attenuators are seldom more precise than ±0.1 dB. This will be reflected upon the LR-BPM X and Y zero readings.
Connect to Test Kit or 19” BPM-RFC chassis to AC mains.

Observe the traces from:

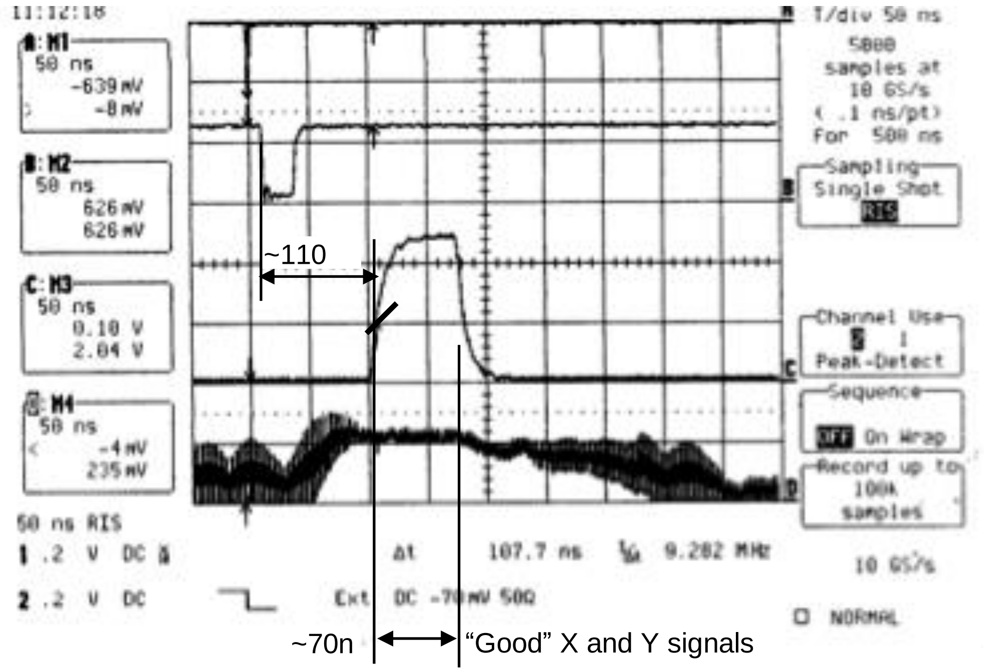
- Auxiliary trigger output: ~13 ns after bunch. This output is used for oscilloscope triggering.
- Trigger output for ADC: 110 ns after the bunch. This trigger is used to trigger ADC.
- X or Y output: signal can be measured; it is held for ~70 ns.
-

Input signal from pickup

Trigger output
BTG/BT.AUX.OUT
from Built-in Beam Trigger
or External Trigger

Trigger output for ADC
TG.ADC.OUT
from Built-in Beam Trigger
or External Trigger
+ Track&Hold delay
Note: Positive edge selected

Position output signal
XOUT or YOUT



Next, proceed thru the same tests as "QUICK CHECK: LR-BPM in Sample & Hold Mode":

- XOUT and YOUT Zero Offsets
- Simulating beam position changes

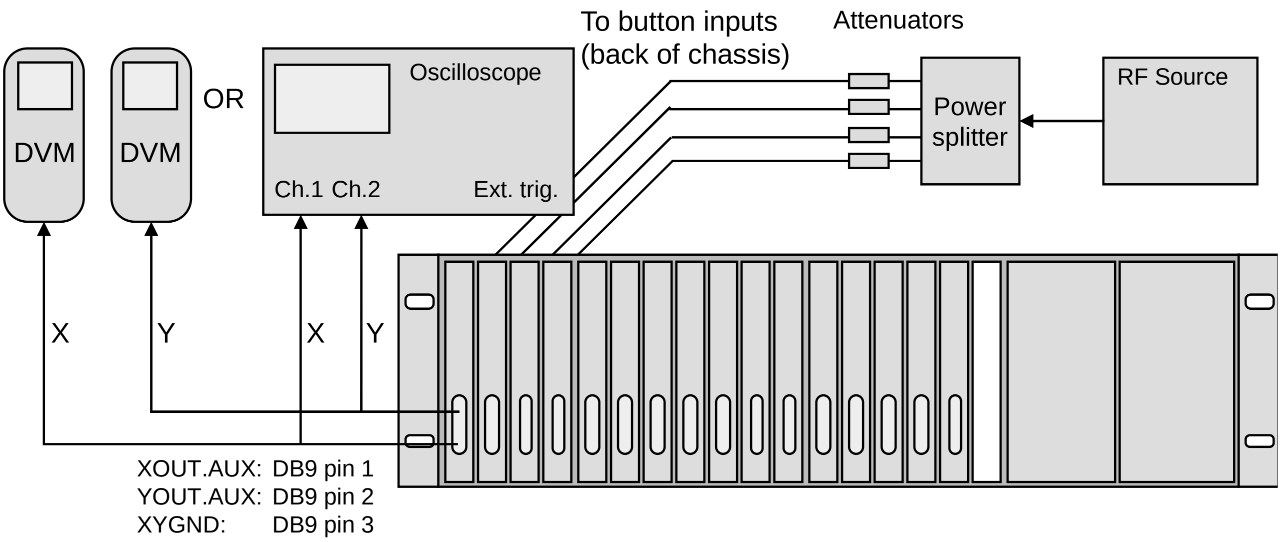
Noise measurement cannot be performed as easily in Track&Hold mode, because the output signal is held only ~70ns. For noise measurement, X or Y output must be sampled, using either Auxiliary Trigger, or ADC Trigger.

QUICK CHECK: LR-BPM IN TRACK CONTINUOUS MODE

If you wish to use an LR-BPM (whether or not it has the Sample & Hold option LR-BPM-SH), its switches must be set to according to chapter TRACK-CONTINUOUS MODE. Unless otherwise specified, LR-BPM without Sample&Hold LR-BPM-SH option has following ex-factory settings:

- Rotated pickups
- Mode: Track-Continuous
- Built-in trigger: Enabled
- ADC Trigger output: positive edge

Setup: to check immediately that your LR-BPM system is working.



To display X and Y signals, you can use either two DVMs, or an oscilloscope.
Attach the equipment together as shown above.

Set the DVMs on Volt-DC, or the oscilloscope on:

- Time base on 0.2 ms / div., free running,
- Channel 1 to Xout signal, sensitivity 0.2 V / div., 1 MΩ DC coupling
- Channel 2 to Yout signal, sensitivity 0.2 V / div., 1 MΩ DC coupling

Set the RF source to the LR-BPM operating frequency.
E.g. set to 500 MHz to test LR-BPM-500MHz.
Amplitude ca. -10 dBm

Use 4 similar attenuators, each 3 dB. The same test can be done with 5 and 10 dB.
Note: attenuators are seldom more precise than ±0.1 dB. This will be reflected upon the LR-BPM X and Y readings.

Note: Signals applied to LR-BPM inputs will be attenuated by the 4-way splitter:

- Transformer-type 4-way splitters typically attenuate by 7dB, 4-way resistive splitters or cascaded 2-way splitters attenuate by 12dB.

Connect to Test Kit or 19” BPM-RFC chassis to AC mains, the DVM (or oscilloscope) will display X and Y values.
If the RF signals applied to all four LR-BPM inputs were exactly equal, and if the LR-BPM module were perfect, the values of X and Y would be exactly 0 Volt.
This is generally not the case, X and Y will be many 10s or even 100s of millivolts off.

You can determine how much of this offset is caused by attenuator inequality:
- Swap the attenuators A and C, then B and D and observe the offset change.

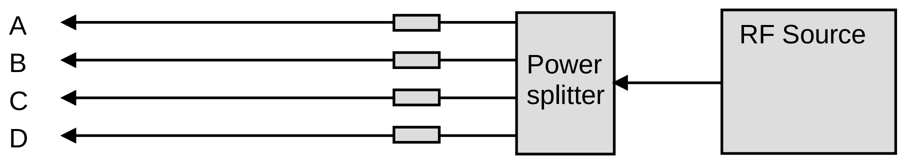
You can determine how much of this offset is caused by power splitter imbalance:
- Instead of connecting attenuator A to power splitter output 1, connect it to output 3 and connect attenuator C to output 1.
- Do the same for attenuators B and D with power splitter outputs 2 and 4.

The next tests will consist of:
- Simulating beam displacements of 6 dB, 10 dB and 14 dB
- Exploring the LR-BPM dynamic range by varying the RF source output power.

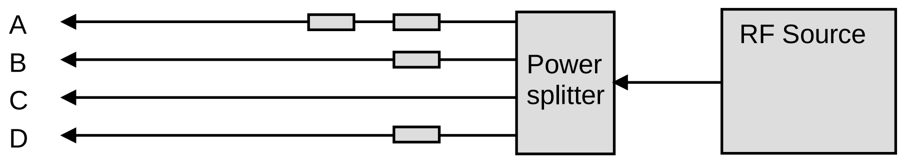
Beam displacement

The RF source output power should be in the range -10dBm ... -35 dBm

The LR-BPM on-center sensitivity is factory-set to 55.5 mV per dB of signal difference between opposite pickups. For pickups with small angle (e.g. buttons), 6 dB corresponds to beam displacement equal to 1/6 of vacuum chamber radius. As the beam goes off center, this sensitivity becomes lower due to the algorithm X = Log (A/C). Please consider that the pickup sensitivity becomes higher as the beam goes off center, and one non-linearity tends to compensate the other.
Before simulating a beam displacement, start by noting the X and Y zero offsets, using four equal attenuators:



Then simulate the displacement by removing an attenuator from one input and inserting it in the opposite input: A <=> C, and B <=> D.
Example:



Attenuator C is removed from input C, and added to input A, thus simulating a displacement of the beam towards C (stronger signal on C pickup).

The following combinations can be tried, yielding the X and Y values listed here.
Please note these are displacements. Take the zero offsets due to power splitter imbalance and attenuators inequality into consideration.

LR-BPM modules are factory preset:

- For orthogonally placed pickups: up, down, left and right
  Or
- For rotated pickups: upper-right, upper-left, lower-left and lower-right.

The combinations on the following table can be tried, yielding the X and Y values listed.

Note: These are displacements. Take into consideration the zero offsets due to power splitter imbalance and attenuators inequality.

Table of X/Y output voltage vs. input power

Input	Attenuators	Equivalent displacement	Rotated pickups	Orthogonal pickups
A	3 + 3	1/6 of radius towards C		
B	3		X = -0.245 V	X = -0.347 V
C	0		Y = -0.245 V	Y = 0 V
D	3	(button pickups << chamber diameter)		
A	3 + 3	1/6 of radius towards C		
B	3 + 3	1/6 of radius towards D	X = 0 V	X = -0.347 V
C	0		Y = -0.490 V	Y = -0.347 V
D	0	(button pickups << chamber diameter)		
A	5 + 5	1/4 of radius towards C		
B	5		X = -0.407 V	X = -0.576 V
C	0		Y = -0.407 V	Y = 0 V
D	5	(button pickups << chamber diameter)		
A	5 + 5			
B	5 + 5		X = 0 V	X = -0.576 V
C	0		Y = -0.814 V	Y = -0.576 V
D	0	(button pickups << chamber diameter)		
A	10 + 7	1/3 of radius towards C		
B	10		X = -0.570 V	X = -0.806 V
C	3		Y = -0.570 V	Y = 0 V
D	10	(button pickups << chamber diameter)		

Note: These are displacements. Take into consideration the zero offsets due to power splitter imbalance and attenuators inequality.

The above voltages are representations of the algorithms:

For Orthogonal pickups:
- $X = K_X \, Log(A/C)$
- $Y = K_Y \, Log(B/D)$

For Rotated pickups:
- $X = K_X \, [Log(A/C) - Log(B/D)] \cos(\beta)$
- $Y = K_Y \, [Log(A/C) + Log(B/D)] \sin(\beta)$.

Where β is the tilt angle of the pickup axes. Refer to AGREEMENT on AXES and SIGNS.

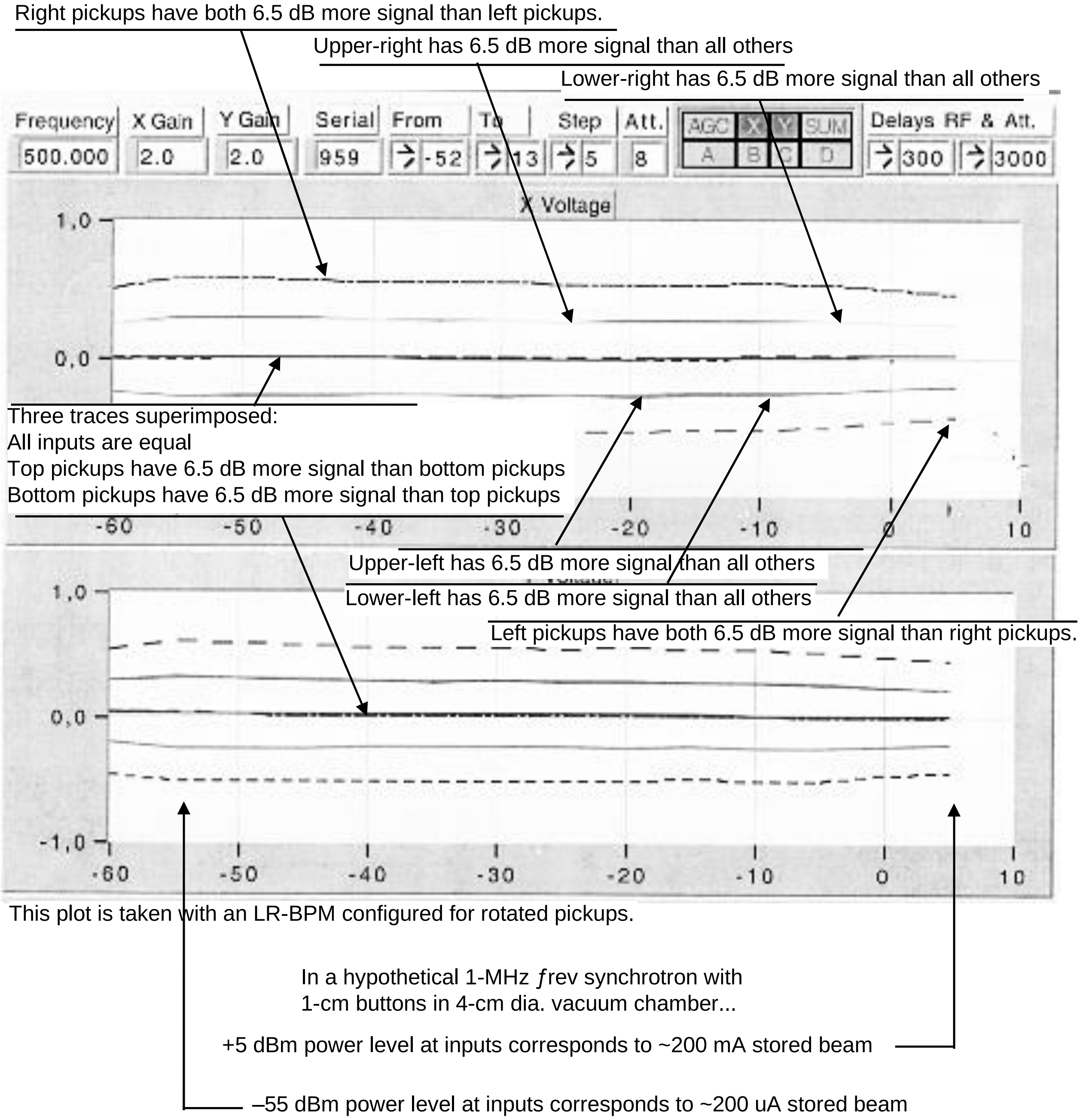
$K_X.\cos(\beta)$ and $K_Y.\sin(\beta)$ are factory-set to 1.1513 Volts

Note: This value was chosen because it corresponds to a difference-over-sum ratio equal to 1 for small amplitude displacements off-center. E.g. 0.001 V for 0.005 x R.

Explore the dynamic range

Set the input attenuators is such way that X and Y are off center.
Vary the power from the RF source to simulate beam intensity variations.
Explore the range from +7 dBm down to -70 dBm.

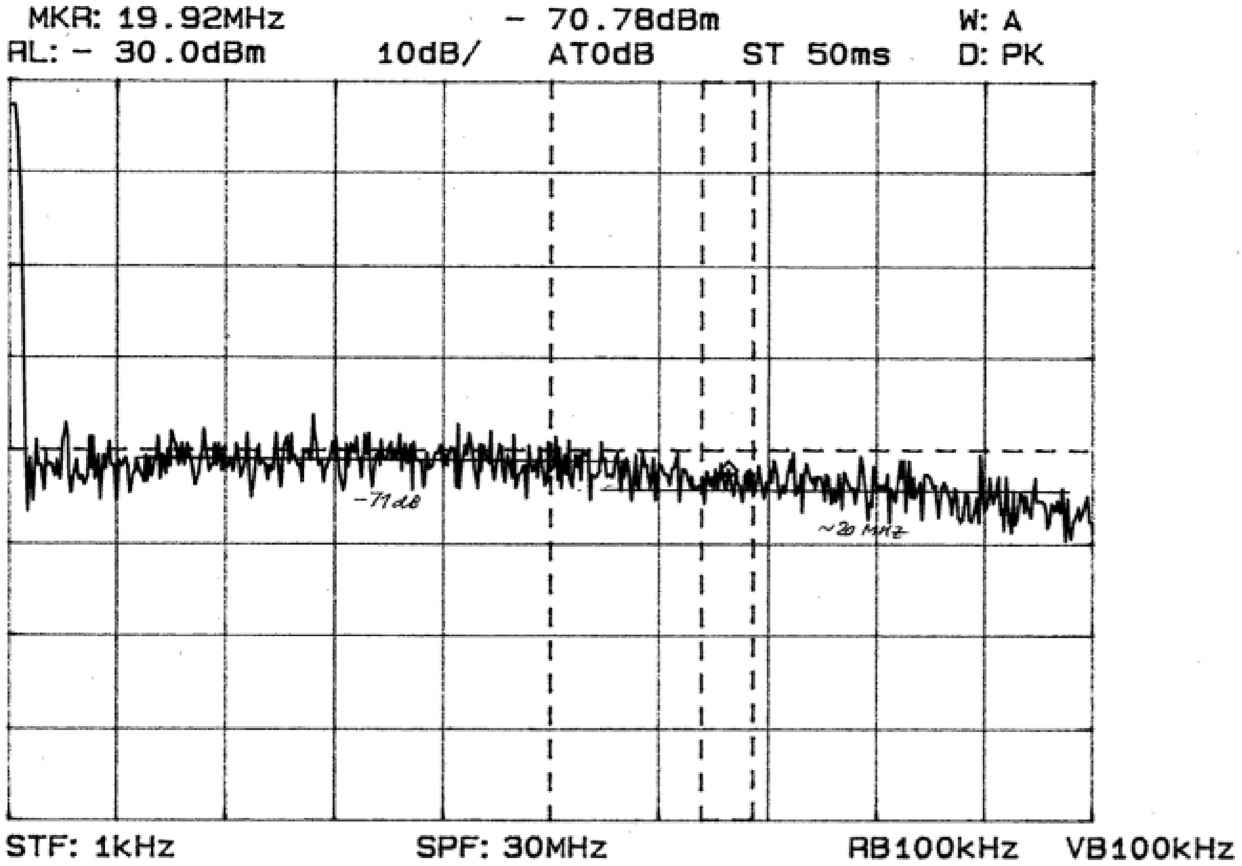
Remember that 4-way transformer-type splitters absorb typically 7 dB and resistive splitters absorb 12 dB.



While the RF source output power is changed, observe the intensity dependence of X and Y outputs on the voltmeters. The X and Y output voltages vary with input power applied to the LR-BPM inputs.

Noise spectrum

Observe the noise spectrum with an FFT or baseband spectrum analyzer, at various input signal levels. The output noise spectrum looks like:



Noise over 1 kHz to 30 MHz bandwidth, with 100 kHz resolution bandwidth.
Plot taken with Anritsu 2601B Spectrum analyzer.
Probe -20 dB.
Input signal level -30 dBm.

Comments on measurement:

- Noise = -71 dBm + 20 dB (probe) = -51 dBm = 0.63 mVrms in 100 kHz
- Noise density = 0.63 mV / √100 kHz = 2 µV/√Hz
- Noise rms over 20 MHz = 2 µV/√Hz x √20MHz = ~10 mVrms

Putting the noise spectrum in perspective:

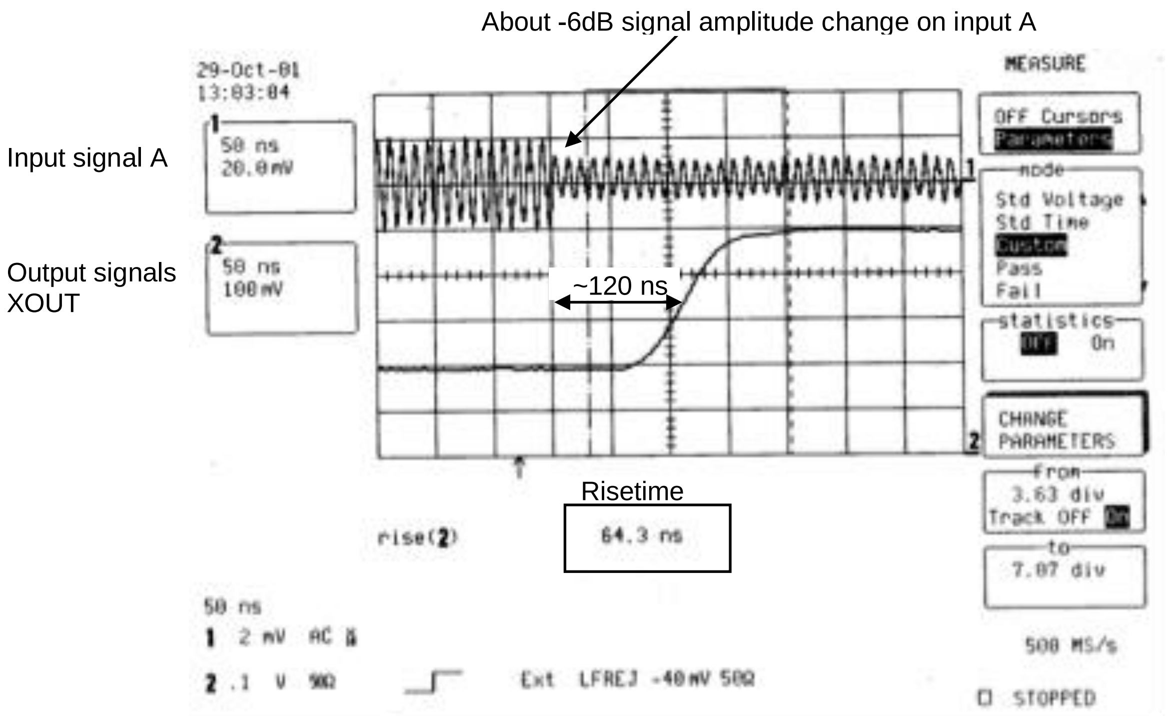
- On-center sensitivity is 39.2 mV/dB for rotated pickups.
- With XOUT and YOUT = 39.2 mV, the displacement is ≈0.03 of radius.

Thus 10 mV rms noise over 20 MHz is 1/140 of vacuum chamber radius. Say, 150 µm rms in a 20-mm radius vacuum chamber.

LR-BPM REACTION TIME TO BEAM POSITION CHANGE

LR-BPM can be used for fast interlock machine protection systems:

Time delay from a beam position change to Output signal half-height rise is ~120 ns
Output risetime is ~65 ns



Example from Orthogonal pickups configuration.

SIGNALS

Input signals

BUTA BUTB BUTC BUTD	Pickup inputs A, B, C, and D. Impedance 50Ω. See Agreement on Axes & Signs, this manual, for pickup assignments.

Output signals for ADC

XOUT	X displacement. Bipolar signal up to ±2V (0 Volt represents pickup center) Output impedance: 100 Ω
YOUT	Y displacement. Bipolar signal up to ±2V (0 Volt represents pickup center) Output impedance: 100 Ω
XGND	Analog ground for XOUT
YGND	Analog ground for YOUT
SUM.OUT	- (LogA + LogB + LogC + LogD) signal Signal range 0...−2V Output impedance: 100 Ω
TG.ADC.OUT	Trigger for external ADC TTL pos/neg. edge (See QUICK CHECK: Sample&Hold Mode -and- Track&Hold Mode) Output Impedance 100 Ω.
SUM&TG.GND	Ground for SUM.OUT -and- TG.ADC.OUT
VPHOUT	Phase angle output ±9V = ±90° RF to Phase reference angle (LR-BPM with BPPM option only)

Auxiliary Output Signals

XOUT.AUX	Same as XOUT, but 50-Ω output impedance
YOUT.AUX	Same as YOUT, but 50-Ω output impedance
XYGND	Analog ground for XOUT.AUX and YOUT.AUX

External Trigger Input and Trigger Gate

TRG.IN.AUX	Input for external trigger 50 Ω, positive edge > 2 V
TRG.GATE	Input for gating the beam trigger TTL, High-Low-High High state inhibits Built-in Beam Trigger Low state (default state) allows Built-in Beam Trigger.
SUM&TRG.GND	Ground for TRG.IN.AUX -and- TRG.GATE.

External Controls

TRACK.CONTINUOUS	TTL signal. To set Track-Continuous mode. High state (default) sets Track&Hold mode. Pull down for Track-Continuous mode. Pullup resistor 4K7 to 5V.
GND	Ground for above signals.

Common external controls

Common external controls are controls which are common to all BPM modules in a BPM chassis.

None are handled by LR-BPM

CONNECTORS PINS ALLOCATION Rev. 2.1

Description	Signal	DB9 female connector on LR-BPM front panel	DIN41612M LR-BPM module rear connector	DB15 female connector on BPM-RFC rear panel (one connector per BPM station)
INPUT SIGNALS				
Input A	BUTA		b2 *	
Input B	BUTB		b5 *	
Input C	BUTC		b8 *	
Input D	BUTD		b11 *	
Phase reference (BPM option only)	PHREF		b22*	
*Coaxial insert 1.0/2.3 type				
OUTPUT SIGNALS FOR ADC				
X output	XOUT		a15	8
Analog ground	XGND		a20	15
Y output	YOUT		a18	7
Analog ground	YGND		a17	6
Log (A, B, C, D) output	SUM.OUT		c20	3
ADC Trigger TTL output pos/neg edge	TRG.ADC.OUT		b20	5
Phase voltage output (BPPM option only)	VPHOUT	4	b19	4
AUXILIARY OUTPUT SIGNALS				
X auxiliary output	XOUT.AUX	1		
Y auxiliary output	YOUT.AUX	2		
X and Y auxiliary outputs analog ground	XYGND	3		
Beam/Ext. trigger output position edge	TRG.OUT.AUX	9		
EXTERNAL TRIGGER INPUT AND TRIGGER GATE				
External trigger input pos. edge	TRG.IN.AUX		c19	2
Trigger inhibit gate Low-High-Low**	TRG.GATE		b14	10
Trigger & Gate ground	SUM1TRG.GND	4	b19	4
**Default value: High, no inhibiting				
EXTERNAL CONTROLS				
Track-Continuous mode, Low	TRACK.CONTINUOUS	7		
Ground	GND	6	a14	13
POWER SUPPLY				
+ 8 … 15 V	+15V		c13	
- 8 … 15 V	-15V		c15	
Common	COM		c14	

BPM CABLES LAYOUT INSTALLATION

Cables electrical length must be equal within ±1ns. Yet, unlike most BPM electronics, the LR-BPM module does not require the input signals to be in phase. It tolerates any phase change, even 180°.

Unnecessary intermediate connectors should be avoided. When –for practical reasons– patch-panels must be used, the cables on either side of the patch-panel should be passed through tubular ferrite cores. Ferrite material must have high permeability at the BPM operating frequency.

The four cables pertaining to the same BPM stations must be laid side by side. Cables, BPM chassis and modules should be kept away –as much as possible– from RF equipment, klystrons, cavities.

Connectors must be chosen carefully to match the cable used. Connectors manufacturer's instructions must be followed meticulously. If cable layout is subcontracted, subcontractors must be informed of the extreme reliability expected from these cables. All cables with connectors must be checked before installation with a network analyzer, up to twice the operating frequency at least; i.e. up to 1 GHz for 500 MHz operating frequency.

BPM modules must be installed in an RF-shielded chassis.

BPM CHASSIS

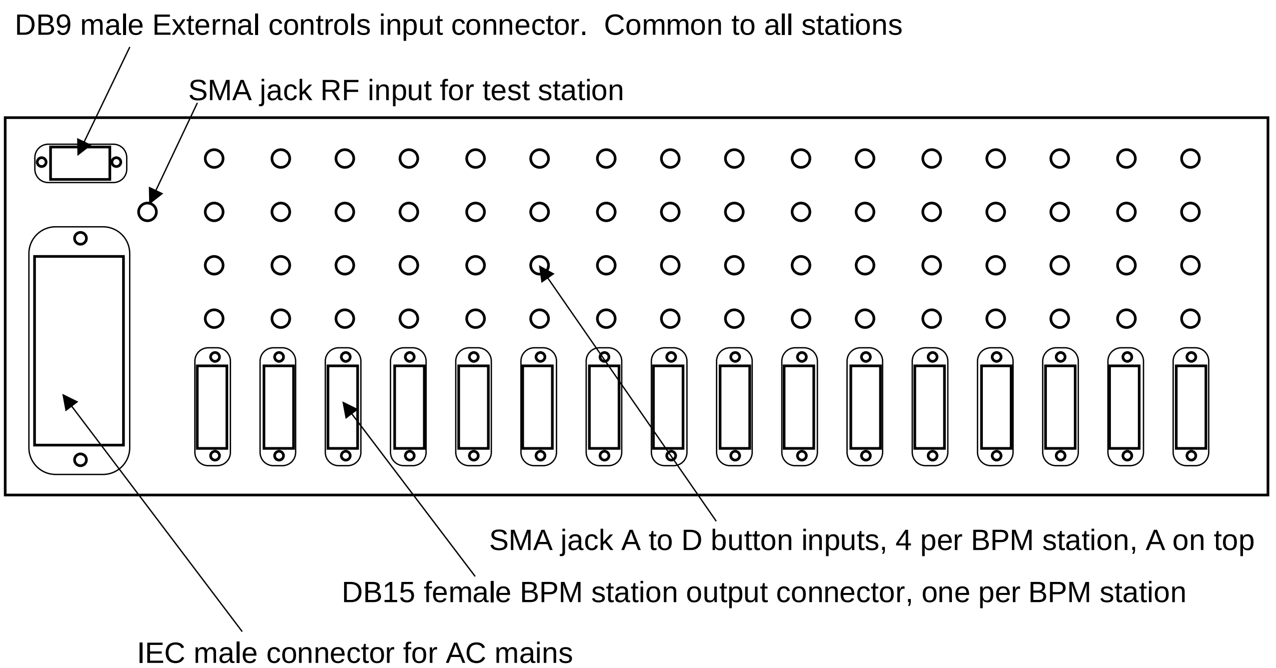
Specifications

The BPM-RFC/X chassis is built around a 19” Schroff rackable RF chassis.
Dimensions of the bin: 3U x 84F
Schroff reference: Europac Lab HF/RF #20845-283

The BPM-RFC/X is available equipped for 1 up to 16 BPM stations. X being the number of stations.

BPM-RFC/X with less than 16 stations are partially equipped BPM-RFC/16. As a result, all BPM chassis are field-upgradable to the full 16-station chassis.

Chassis rear view

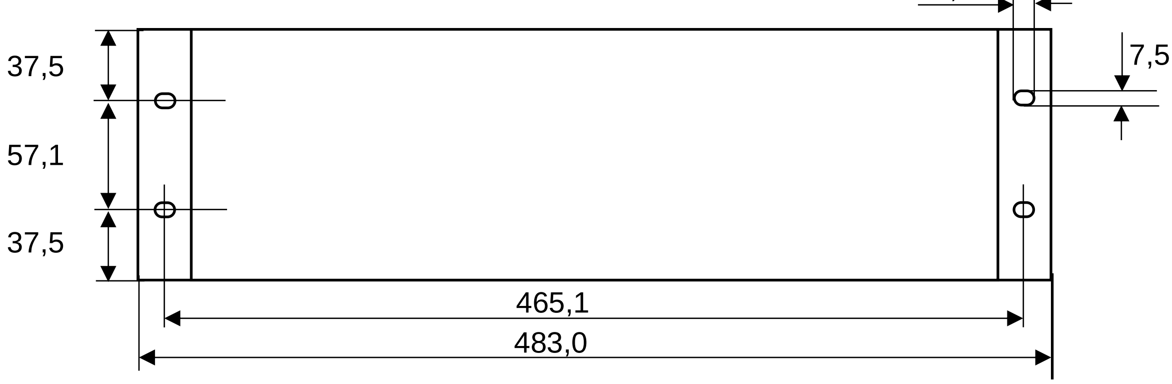


Power Supply module

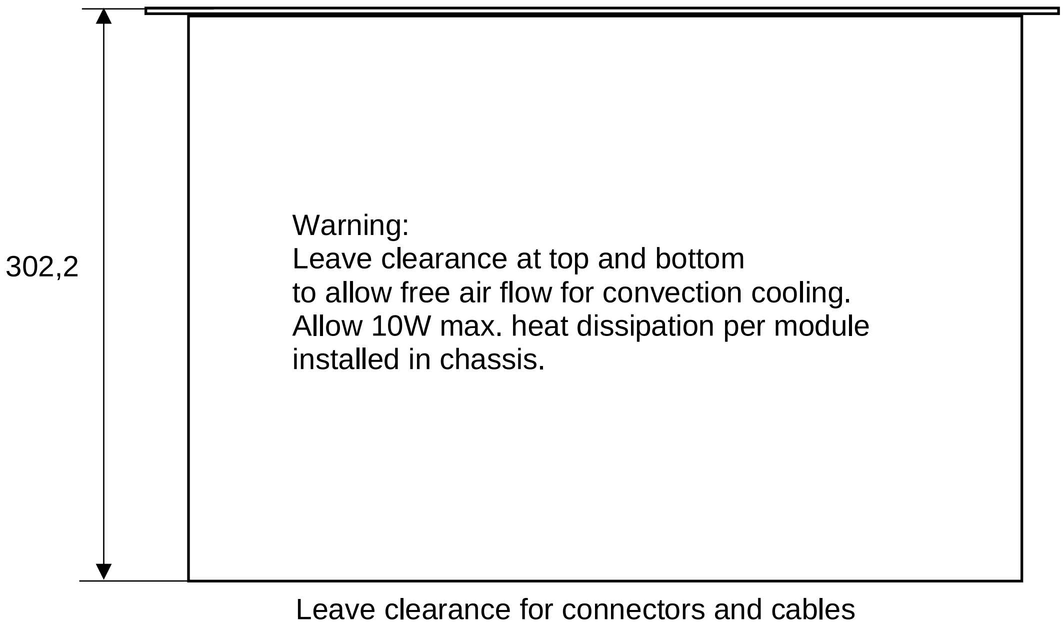
AC mains voltage	Universal Input 85…264Vac, 47-440Hz
Output	± 15 V
Power	15 W
Efficiency	79% at maximum load
Inrush current	limited to 15A max.
Dimensions	per DIN41494: 3U high, 8F wide, 160mm deep
Manufacturer	MinMax (Taiwan)
Model	AKF-15D15

Outer dimensions

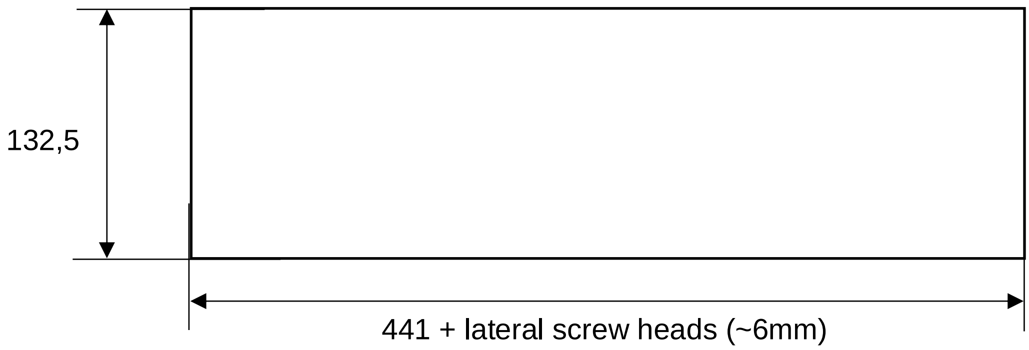
Front view



Top view



Rear view



BPM MODULE REAR CONNECTOR DIN41612M 24+8

Note: For connections, See Connector Pins Allocation, this manual.

BPM chassis for 1 up to 16 BPM modules are part of Bergoz Instrumentation sales program (BPM-RFC/X) and include the necessary mating connectors (See BPM chassis, this manual).

More information and latest manuals revisions can be found on our website

www.bergoz.com

If you have any questions, feel free to contact us by e-mail

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