BOAT BPM MANUAL

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INTRODUCTION.

Loss of the stored beam in an uncontrolled manner can cause damage to Pep-II B Factory. The big-orbit abort trigger beam position monitor (BOAT BPM) detects large beam position excursions or unexpected beam loss and triggers the beam abort system to extract the stored beam safely.

1.0 BOAT BPM DESCRIPTION.

The maximum stored energy in the PEP-II rings, 200 kJ for the high-energy ring (HER) at 3 A current and 9 GeV energy, and 77 kJ for the low-energy ring (LER) at 3 A and 3.5 GeV, can melt through the vacuum chamber if the impact is localized. A beam abort trigger system (BATS) protects each ring by kicking the beam into a dump in one turn, spreading it across an exit window to avoid damage. The BATS has been installed around the rings to receive triggers from a variety of faults (such as loss of rf power, loss of dipole current, etc.) and abort the appropriate ring. A new addition to this trigger network is the BOAT BPM.

To detect large beam position offsets, two sets of beam position monitor buttons are installed in HER and LER (Fig. 1). A third set of buttons is used for additional measurements of the X position at a dispersive region, to trigger on a rapid change in position *(dX/dt)* due to energy loss in the first ten turns after an rf trip. The buttons locations are shown in table 1.

TABLE 1. The beam position monitor buttons location.

Ring	Region	relative phase *X*, degrees	relative phase *Y*, degrees	Unit number	near Quad	chamber type
LER	10	0	0	ABPM-PR10-2011	QDWA	circular
LER	10	102	66	ABPM-PR10-2031	QDW8A	elliptical
LER	10	453	330	BPMS-PR10-2142	QFW1A	circular
HER	8	0	0	ABPM-PR08-8012	QDRFC	circular
HER	8	86	95	ABPM-PR08-8042	QFRFC	circular
HER	9	370	340	BPMS-PR08-9042	QFS2E	octagonal

The sum of the signals from the third set of buttons is proportional to the total current in the ring. It is used to measure beam current and beam current loss rate *(dI/dt)*.

The BOAT BPM module has six daughter boards, mounted on a mother board. There are two types of daughter boards - logarithmic rf (logrf) and linear rf (linrf). There are five logrf and one linrf board on a module.

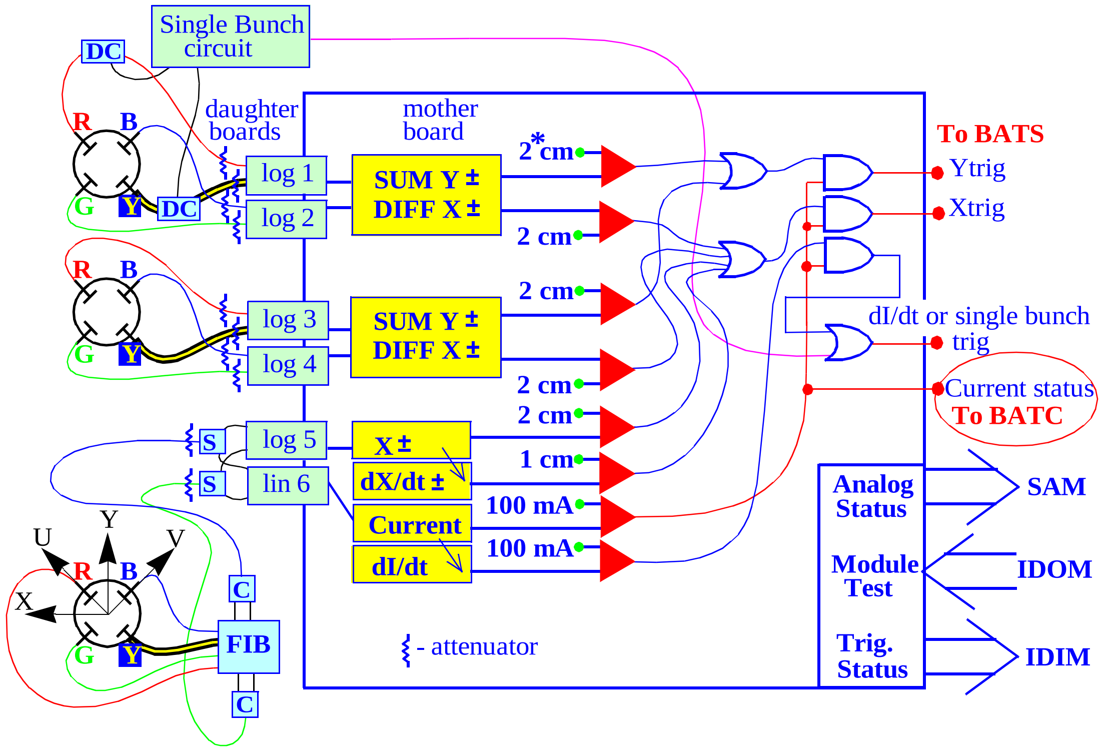

FIGURE 1. The BOAT BPM cabling, module, and interface block diagram. Red, Green, Blue, and Yellow are cable color codes. C is a combiner, S - splitter, DC - directional coupler. 2 cm, 1 cm and 100 mA are the comparators thresholds values *see table (Tab. 2), FIB - Filter Isolation Box.

The signals from two buttons (R and Y, B and G) go to a logrf board (Fig. 1) through 10 dB 25 W attenuators. The logrf board output signal is proportional to the *U* or *V* beam orbit position (*U* - logrf 1 and logrf 3, *V* - logrf 2 and logrf 4). The logrf 5 measures *X* beam orbit position at the dispersive region. The signals from two logrf boards go to the mother board sum and difference amplifier. The sum and difference outputs are proportional to *Y* and *X* beam position respectively. Amplifier gain is set so, that measured voltage to position ratio is 1 V / 1 cm. The bipolar *X* and *Y* beam position signals go to comparators with individually adjusted 20 mm thresholds.

In the third set, the signals from buttons go to modified Filter Isolation Box (FIB), then signals from additional outputs, symmetric to the *X* axis, are combined together, so logrf 5 board measures *X* position at the dispersive region. The normalized *X* position signal goes to a comparator and to a *dX/dt* filter. The *dX/dt* comparator threshold level is 10 mm.

The linrf board (board 6) has the same input signals as the board 5. The linrf board output signal is proportional to the beam current in a linear way. A measured voltage to beam current ratio is 1 V / 1 A. Normalized current goes to a comparator and a *dI/dt* filter. Current and *dI/dt* comparators have a threshold level of 100 mA.

Signals from directional couplers (first set of buttons) go to *Single Bunch* box.

TABLE 2. BOAT BPM LER and HER thresholds; * less than 2 V due to rf board offset.

Trigger	X1	X2	X3	dX/dt	Y1	Y2	dI/dt	I	Single Bunch
LER threshold, V	1.998	1.333	1.81*	1.0	1.996	1.333	0.241	0.101	0.125
HER threshold, V	2.0	2.004	1.333	1.0	2.003	2.005	0.250	0.100	0.262

The beam position thresholds volt per cm relation is 1V / 1 cm, 1.333 cm threshold set for elliptical or octagonal chamber. dI/dt threshold adjusted for 100 mA, current threshold adjusted for 100 mA. Single Bunch threshold suppose to be between 3 mA/bunch and 3.5 mA/bunch.

To minimize the number of the inputs to the BATS, the four *X* position outputs are OR-ed together on the mother board, separately from OR-ed *Y* position outputs. An AND gate disables the *X*, *Y* and *dI/dt* outputs if the current is below 100 mA. There are a total of four outputs to BATS *X, Y, dI/dt or Single Bunch* " trip" triggers and *I* (current) status trigger. The output trigger pulse has duration between 6 μs and 10 μs; logic low state (0 V) is trip, high state (+5 V) is ok. The outputs locations are shown in table 3.

TABLE 3. BOAT BPM and BATS connections.

Ring	output trigger description	source BOAT output connector	source BATS code	interface	destination
LER/IR10	Y position	J7	B705-10CC-0735-J7	B705-0731-J4	B705-0724-PR10-CR03-S06-CH04
LER/IR10	X position	J10	B705-10CC-0735-J10	B705-0731-J3	B705-0724-PR10-CR03-S06-CH03
LER/IR10	dI/dt or SB	J9	B705-10CC-0735-J9	B705-0731-J5	B705-0724-PR10-CR03-S06-CH05
LER/IR10	current	J8	B705-10CC-0735-J8	B680-1845-J8	B680-1724-PR08-CR03-S04-ILIM
HER/IR8	Y position	J7	B680-1836-J7	B680-1843-J54	B705-0724-PR10-CR03-S07-CH04
HER/IR8	X position	J10	B680-1836-J10	B680-1843-J53	B705-0724-PR10-CR03-S07-CH03
HER/IR8	dI/dt or SB	J9	B680-1836-J9	B680-1843-J57	B705-0724-PR10-CR03-S07-CH07
HER/IR8	current	J8	B680-1836-J8	B705-10CC-0733-J8	B705-10CC-0724-PR10-CR03-S04-ILIM

The BOAT BPM position signal processing does not depend on external control, all parameters and thresholds are set in hardware in the chassis. To monitor triggers status, analog status and to check the BOAT BPM module functionality, there is an interface with IDIM, IDOM and SAM CAMAC modules [1].

TABLE 4. IDIM, IDOM, SAM CAMAC modules locations.

Ring	Rack	PR / Crate	IDIM	IDOM	SAM
LER	10CC-0724	PR10 / CR03	S14	S15	S16
HER	B680-1824	PR08 / CR04	S17	S18	S19

One BOAT BPM is placed on each ring (table 5).

TABLE 5. BOAT BPMs locations.

Ring	Building	Rack	BOAT BPM chassis elevation	BOAT BPM Attenuators chassis elevation
LER	705	10CC-07	35	38
HER	680	B680-18	36	39

The BOAT BPM module vertical size is 3U (1U=1.75"/44.45 mm - standard unit size), horizontal size - to be mounted on 19" rack. The Attenuators module has the same horizontal size, the vertical size is 2U.

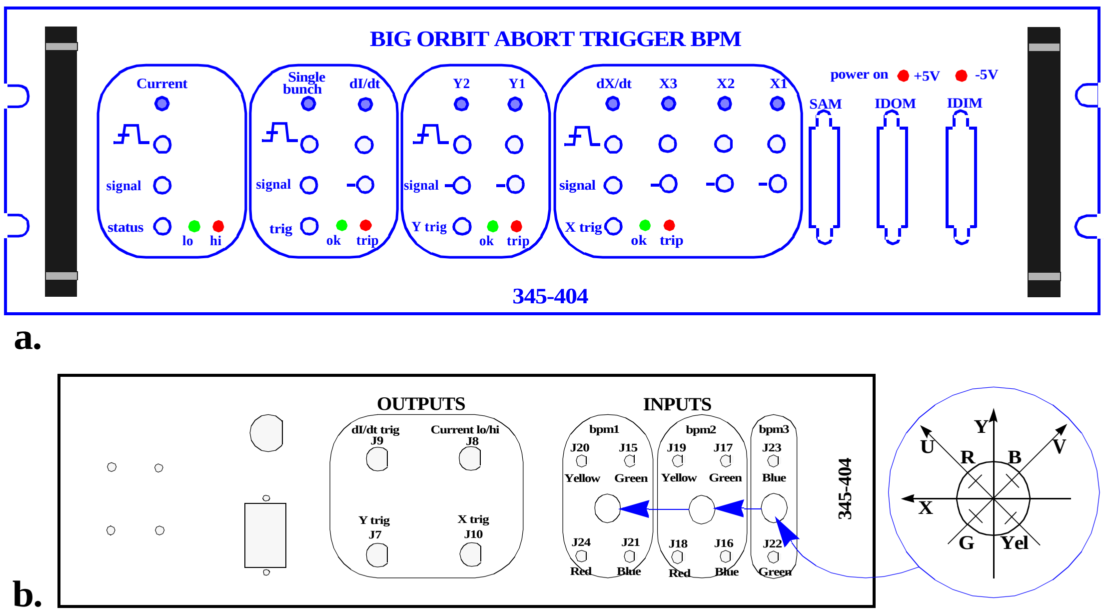

FIGURE 2. The BOAT BPM chassis front (a) and rear (b) panels sketch.

At the right side of the front panel there are three connectors for IDIM, IDOM and SAM CAMAC modules, above them there are LEDs to indicate +5V and -5 V power on/off. At the left side from the connectors there are four blocks, grouped by function. The first one is the " X trigger" block. At the block top there are holes to access the potentiometers for the comparator's thresholds adjustment. The potentiometer knob can be reached with a thin screwdriver. Below them there are " thresholds" test points, the corresponding row label is . When adjusting a threshold, one should plug a voltmeter probe into a test point to check the voltage, he is setting the threshold to. The signal test points are in a third row from the top, labeled " signal". Some of them have additional " -" (minus) label, indicating that signal is inverted. The bottom test point indicates the output trigger status, next to it there are the green and red LEDs to show trigger active " ok" or " trip" status respectively. All test points connectors are LEMO type.

The next blocks are - " Y trigger", " *dI/dt* and Single Bunch trigger" and " Current Status". The " Current Status" block's bottom test point is labeled " status", the green LEDs label is " lo" (low), and the red LEDs label is " hi" (high), indicating that the current is lower or higher than 100 mA respectively.

The label " X1" means that potentiometer and test points in this column belong to the circuit, deriving positions and trigger from the daughter boards 1 and 2. The same is true for a " Y1" label. The labels " X2" and " Y2" are referring to boards 3 and 4, " X3" and " dX/dt"- to board 5, " Current" and " dI/dt" - to board 6.

The SLAC drawing number for this project is 345 - 404, located on the bottom of the front panel (Fig. 2).

The rear panel has ten inputs (SMA F), labeled according to the mother board input connectors reference designators and to the standard cables color code. Each input block corresponds to one set of buttons. In each block, between top and bottom rows there is a diagram of standard buttons locations and colors. The internal module wiring corresponds to it.

Four output connectors (BNC F) are located at the left side from the input blocks. They are labeled according to their functions (*Y* trig, *X* trig, *dI/dt* trig, Current lo/hi) and according to the mother board output connectors reference designators. Next to the output connectors is the power socket and AC fuse. The BOAT BPM module uses standard AC input: 47-63 Hz, 120 VAC.

Attenuator front and rear panels are shown in the figure below (Fig. 3).

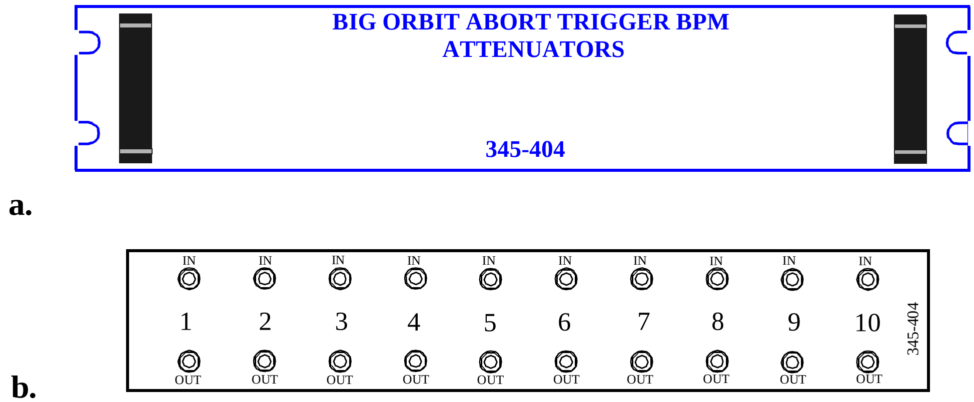

FIGURE 3. The BOAT BPM Attenuators chassis front (a) and rear (b) panels sketch.

25 Watt, 10 dB attenuators are mounted on the chassis to dissipate power from the button electrodes. The cables from buttons go to the chassis inputs (1 to 10), the attenuated output signals go to the BOAT BPM module inputs.

2.0 LOGARITHMIC AND LINEAR RF BOARDS.

The logarithmic board (Fig. 4) has two inputs. Input signals come from two opposite buttons along U or V axis. The signal from the right button (Red for U axis, Blue for V axis) goes to RF IN1, from the left button (Yellow for U axis, Green for V axis) - to RF IN2. The input signal goes through a combiner (C) to a band - pass filter (BPF) with the center frequency 476 MHz and 5 MHz to 6.8 MHz 3 dB bandwidth. The logarithmic amplifier demodulates the filtered signal. The signals from LOG AMP1 and LOG AMP2 go to the difference and sum amplifiers. The difference amplifier output signal is proportional to U or V beam position and goes through the low - pass filter (LPF), designed to suppress 136 kHz (revolution frequency) by 45 dB. By analyzing the DIFF OUT and SUM OUT signals it is possible to check the board inputs connections to the buttons (connected / disconnected).

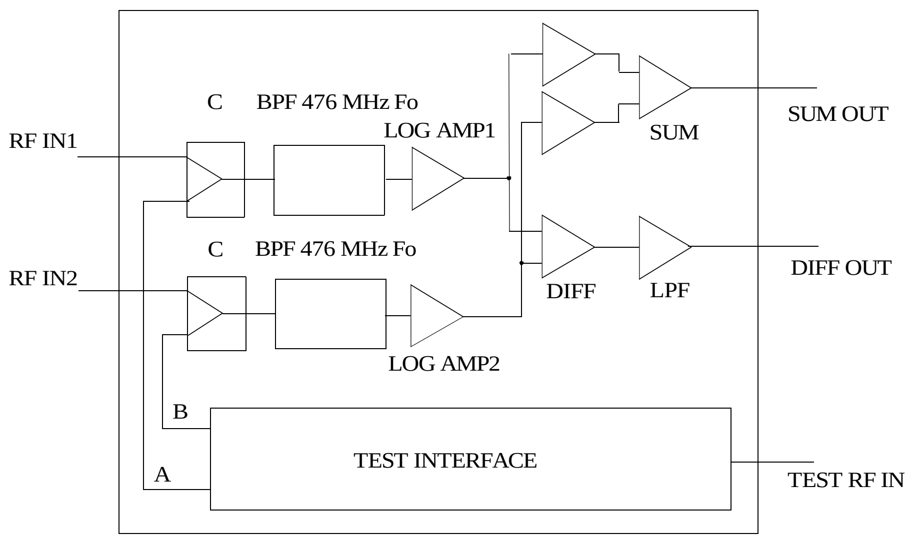

FIGURE 4. Logarithmic rf board diagram. C - combiner, BPF - band-pass filter, Fo - central frequency, LOG AMP - logarithmic amplifier, DIFF - differential amplifier, SUM - summing amplifier, LPF - low-pass filter.

The TEST RF IN signal goes to an rf switch (Fig. 5). The test rf signal (frequency 476 MHz) generated by a local frequency synthesizer on the mother board. If the board is selected for test, the rf switch is closed and the test signal goes through a splitter to the A and B attenuators. The attenuation can be programmed individually in a range from 0 dB to 30 dB in 2 dB steps. By varying the A and B attenuators, beam position offsets can be simulated.

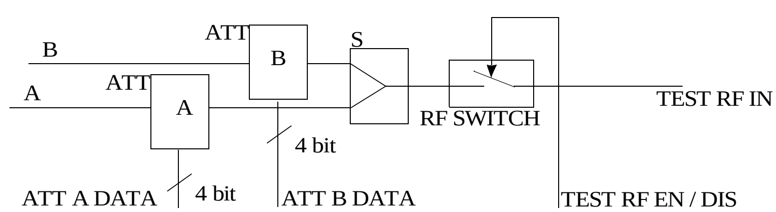

FIGURE 5. The daughter boards test interface. ATT - attenuator, S - splitter.

The linrf board has two dedicated " Receiver/ Mixer/ Limiter /IF Subsystem" chips - to receive two input rf signals (Fig. 6). This chip demodulates the input signal to one at 10.7 MHz if. The advantage of this chip is that one of its outputs is a signal, limited to +- 200 mV and it is stable over a wide dynamic range. These two signals go to a second mixer (MIX2). The MIX2 output is proportional to the board input signal in a linear way.

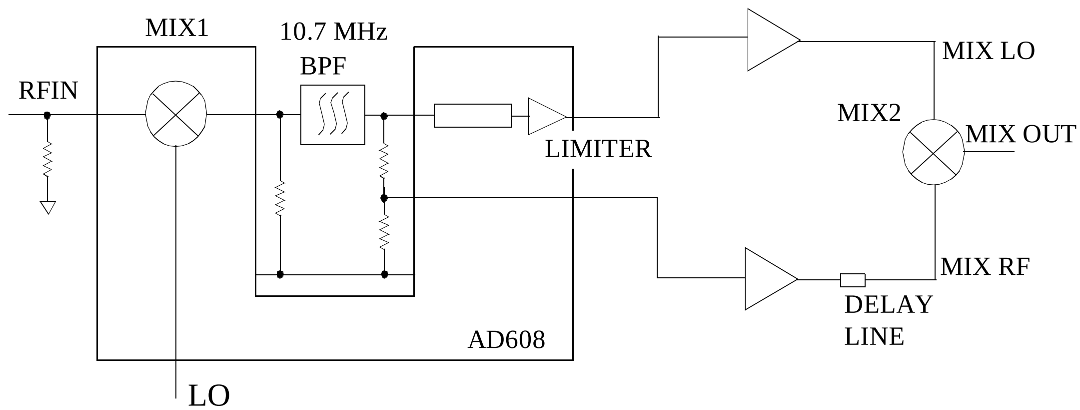

FIGURE 6. The demodulator diagram. MIX - mixer, LO - local oscillator signal.

The local oscillator (LO) signal (at 465.3 MHz frequency) comes from a second frequency synthesizer on the mother board.

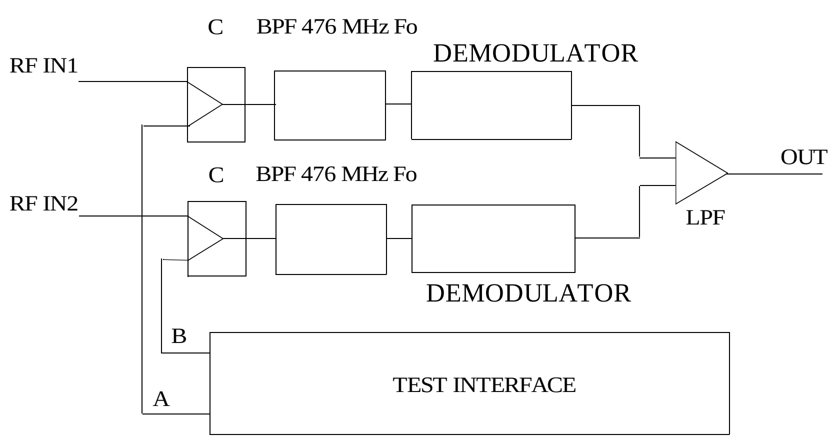

FIGURE 7. The Linear RF board diagram. C - combiner, BPF - band-pass filter, Fo - central frequency, LPF - low-pass filter.

The signals from two identical demodulators (Fig. 7) sum at the LPF section. The LPF is the same as on a logrf board, except that the total gain is higher.

3.0 SINGLE BUNCH INTERLOCK.

A Single Bunch Interlock (SB) detects overcharged bunches, generates a trigger and sends it to the FPGA on the mother board. It is important to have such an interlock, because at excessive charge, the bunch can induce damaging peak power to the beam monitoring equipment, and the feedback amplifiers. Then a lot of effort, time and money will be spent to fix it.

An ultra-fast comparator is used in the SB design as a threshold detector. The comparator has two differential inputs. A beam signal goes to one of those inputs, and a threshold signal goes to the other. The comparator generates an output pulse when the beam signal exceeds the threshold level (Fig. 8).

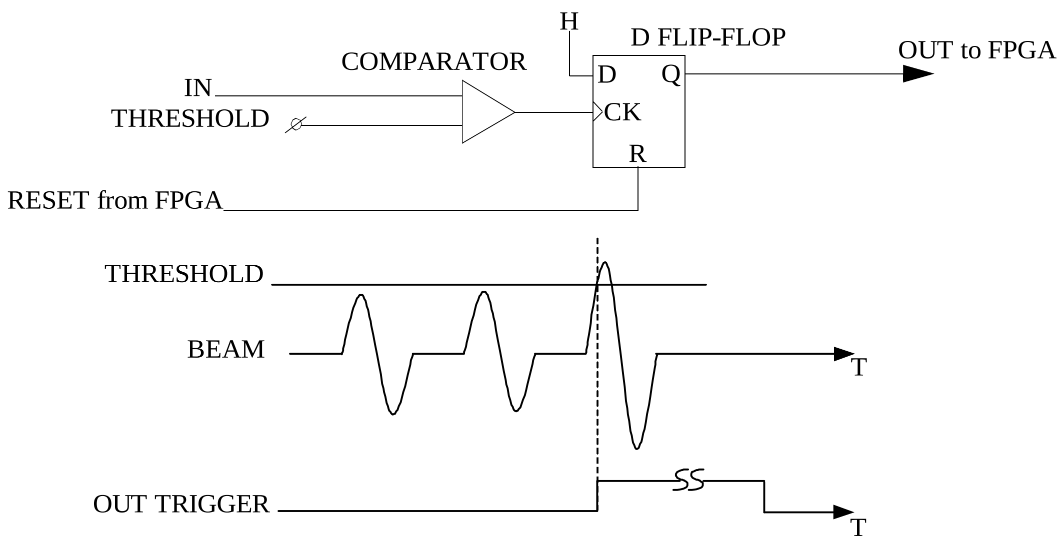

FIGURE 8. The Single Bunch circuit sketch and time diagram.

The HER and LER SB thresholds are adjusted to approximately 3 mA/bunch. Because the *Single Bunch* interlock was not anticipated, it shares a BATS channel with the *dI/dt* interlock.

The SB input is the combined signal of the two buttons (Fig. 9).

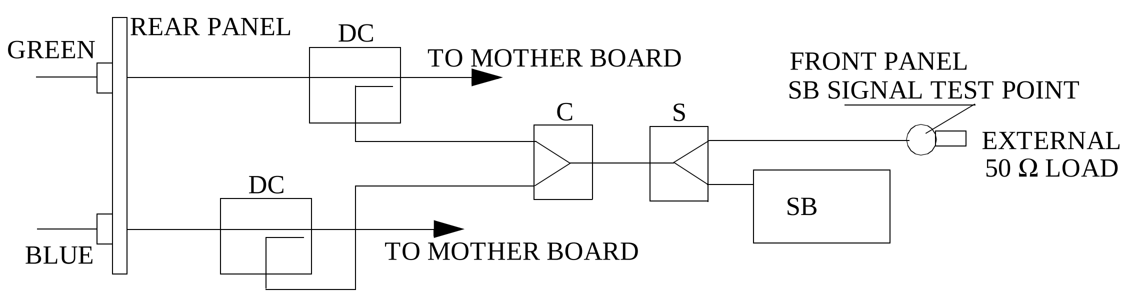

FIGURE 9. The Single Bunch wiring diagram. DC - Directional Coupler, C - Power Combiner, S - Power Splitter.

4.0 MOTHER BOARD.

The BOAT BPM mother board diagram is shown below in figure 8. The signals from two logrf boards go to sum and differential amplifiers. The amplifiers output signals are bipolar *Y* and *X* positions, 1 V / 1 cm. The logrf SUM and DIFF signals are connected to a SAM interface.

All normalized signals go to comparators. The *X*, *Y*, *dX/dt* signals have an additional inverter, so a pair of comparators, belonging to the same bipolar signal has the same threshold. The comparators outputs go to a Field Programmable Gate Array chip (FPGA).

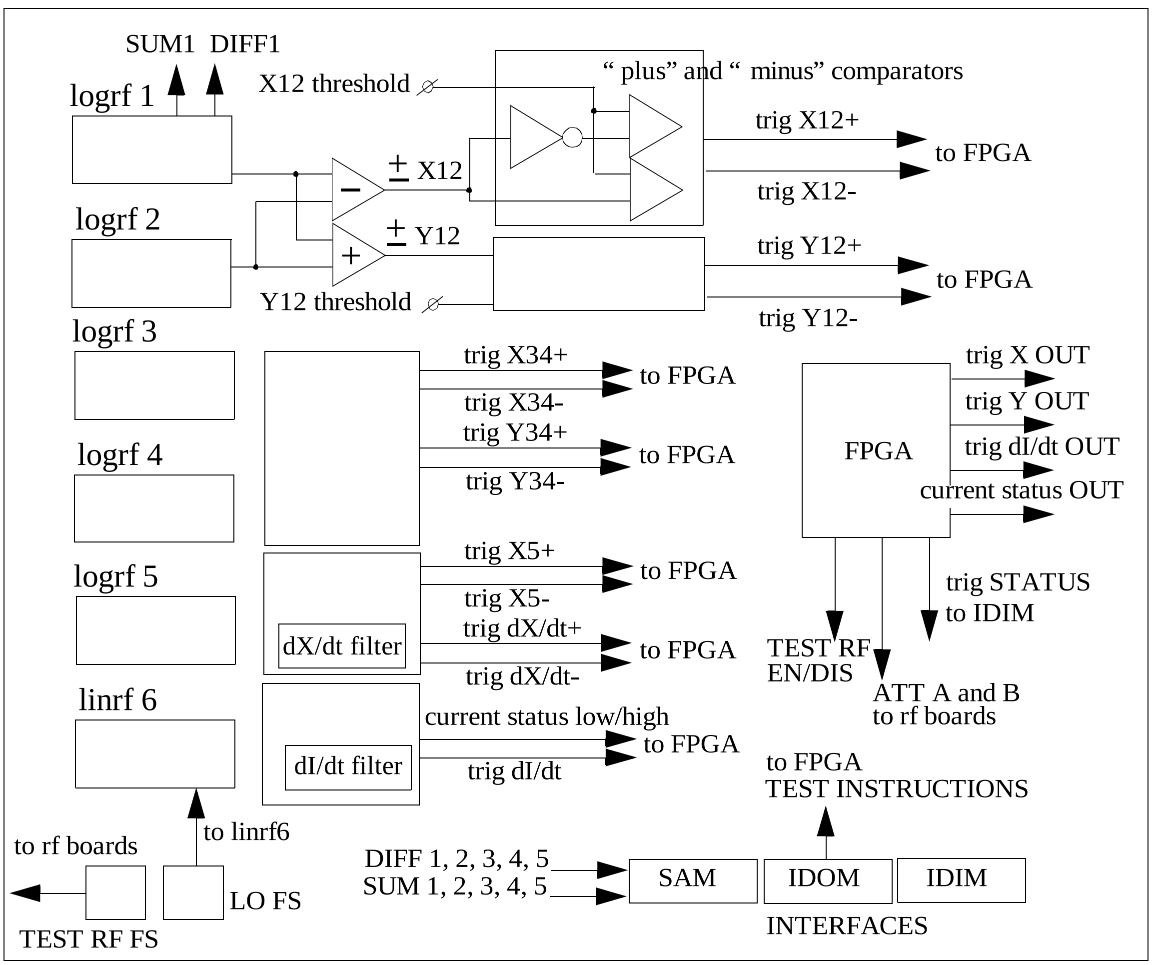

FIGURE 10. The BOAT BPM mother board block diagram. SUM and DIFF are sum and difference signals from the logrf board; FPGA is Field Programmable Gate Array; FS - frequency synthesizer.

Four output trigger signals are generated in a FPGA. Triggers status signals from the FPGA are wired to IDIM interface. The CAMAC instructions, to perform module test, go to the FPGA through the IDOM interface. All rf boards have the same A and B attenuators data, distributed from FPGA. Test RF enable / disable signal and individual rf board select signals are decoded in the FPGA too.

5.0 REQUIREMENTS.

1. The measurements must be averaged over one beam turn (the revolution frequency is 136 kHz) to respond to the total current in the ring and to avoid fill pattern sensitivity.

2. Three regimes of current loss *(dI/dt)* must be recognized:

- Fast, ΔI > 20 mA / 20 μs
- Medium, ΔI > 100 mA / 50 μs < T < 1 s
- Slow, any current loss at time > 1 s

3. The module must measure current in a range from 3A to 100 mA.

4. The module must generate a trigger when

- the beam orbit is off center in " *X*" or " *Y*" by +-20 mm,
- *dX/dt* >= 10 mm in a time less than 1 ms,
- the fast or medium current loss threshold are exceeded,
- the signal bunch overcharge is detected.

5. If the beam current is less than 100 mA, then no trigger should be generated except the *Single Bunch* trigger, since this current is below the threshold of damage.

6. The minimum dynamic range should be 45 dB, where 30 dB is the ratio between 3 A and 100 mA current and 15 dB is the addition due to nonlinear beam-position monitor electrodes behavior at large beam offset.

7. Four triggers should be supplied to the BATS system: *X* and *Y* positions, the current loss rate / single bunch *(dI/dt or Single Bunch)*, and current status, to indicate whether the current exceed 100 mA.

8. The position measurements accuracy should be +-2 mm or better.

9. The 100 mA current measurements accuracy should be +-10 mA or better.

10. No more than one false trigger per week.

5.1 Single Bunch overfill protection requirement.

1. No single bunch should be filled over a limit that is set by an adjustment of the BOAT BPM. The tolerance in the trip point should be a factor of 2, so that a range should be grater than 3 mA and less than 6 mA.

2. If the signal goes over the threshold, the module must generate a trigger.

3. The *Single Bunch* trigger should be OR-ed with the *dI/dt* trigger.

6.0 THE BOAT BPM TEST INTERFACE.

To run the BOAT BPM module test, run a SCP Panel (from either the MCC or SLC VAX). To open " Big Orbit BPM Panel" follow the steps, shown on Fig. 11 below.

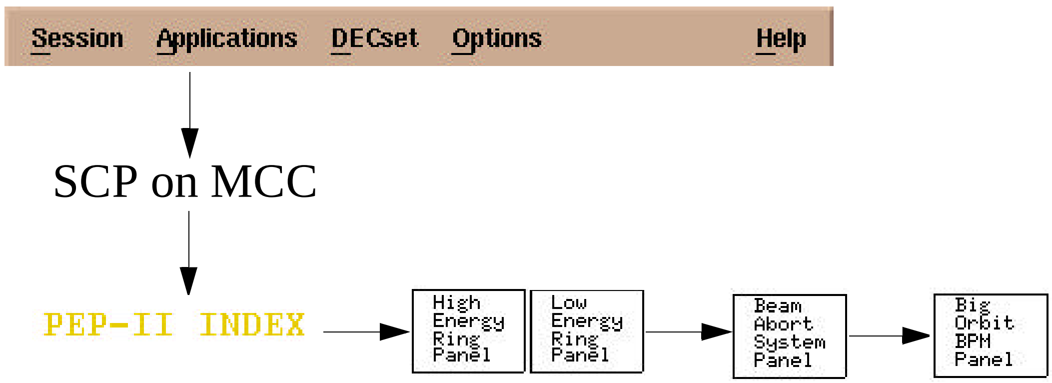

FIGURE 11. A path to the BOAT BPM module software panel.

Under the " Big Orbit BPM Panel" button there is a BOAT BPM interface panel (Fig. 12).

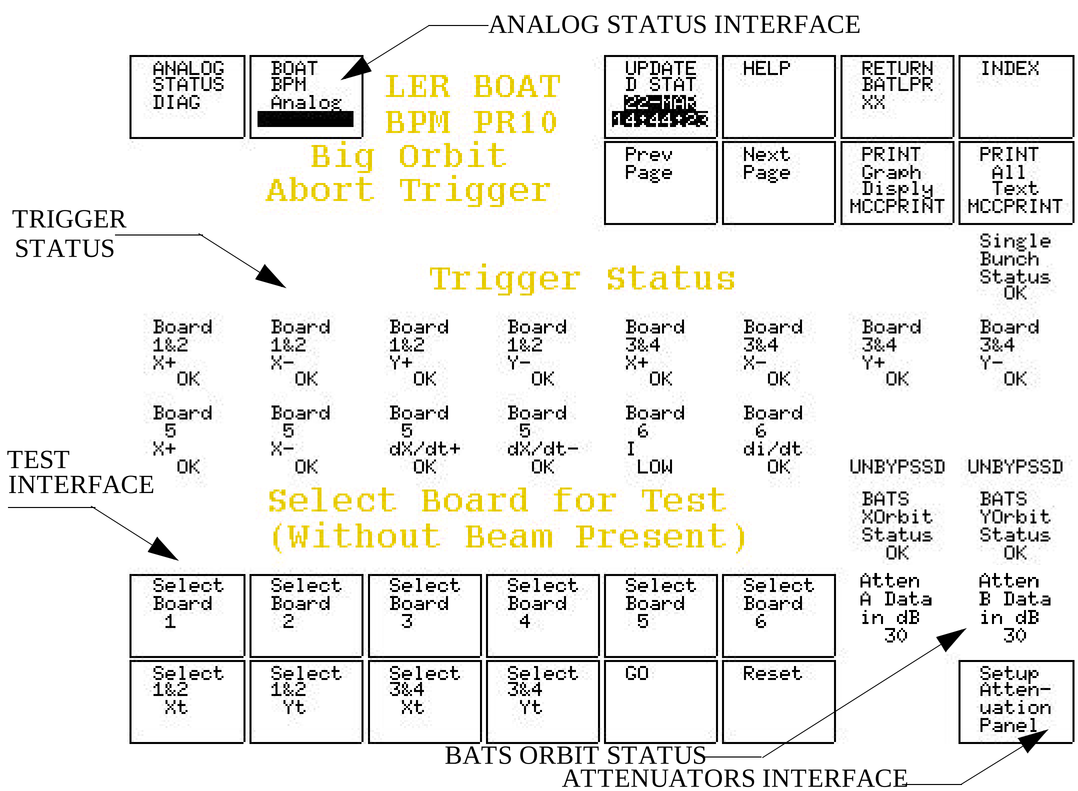

FIGURE 12. The test and status interface panel.

In the middle of the panel screen, below the panel title there is a “ Trigger status” block. The Single-Bunch-Status indicator is located at the right side, next to the block title. The label “ Board 1&2X+” means positive *X* position trigger status is “ ok” or “ trip”. The trigger source is the logrf boards 1 and 2. The first eight indicators show a positive and negative *X* and *Y* beam position offset trigger status from the first and the second sets of buttons. The next four below it, give a bipolar *X* position and *dX/dt* triggers status, and then the last two indicate *I* (current) low / high state and *dI/dt* trigger status. These six indicators are taken from the third set of buttons (see part 1.0 warning). When the signal goes to trip condition, the indicator should change status to “ trip”, and remain in this condition for about 1.5 or 2 minutes. It could be reset any time by pushing “ Reset” button.

The “ test interface” section is located below the “ SELECT BOARD FOR TEST” title. “ Select...” buttons are used to select daughter boards individually (1 to 6), to perform board functionality test or to select particular test as a “ Select 1&2 Xt” - to simulate position offset and to check the trigger condition. **These tests should be performed only without beam.**

Under “ Setup Attenuation Panel” (Fig. 13) there are buttons to set *A* and *B* attenuators loss from 0 dB to 30 dB with a 2 dB step.

Above the attenuators setup buttons there are two indicators - BATS X and Y orbit status.

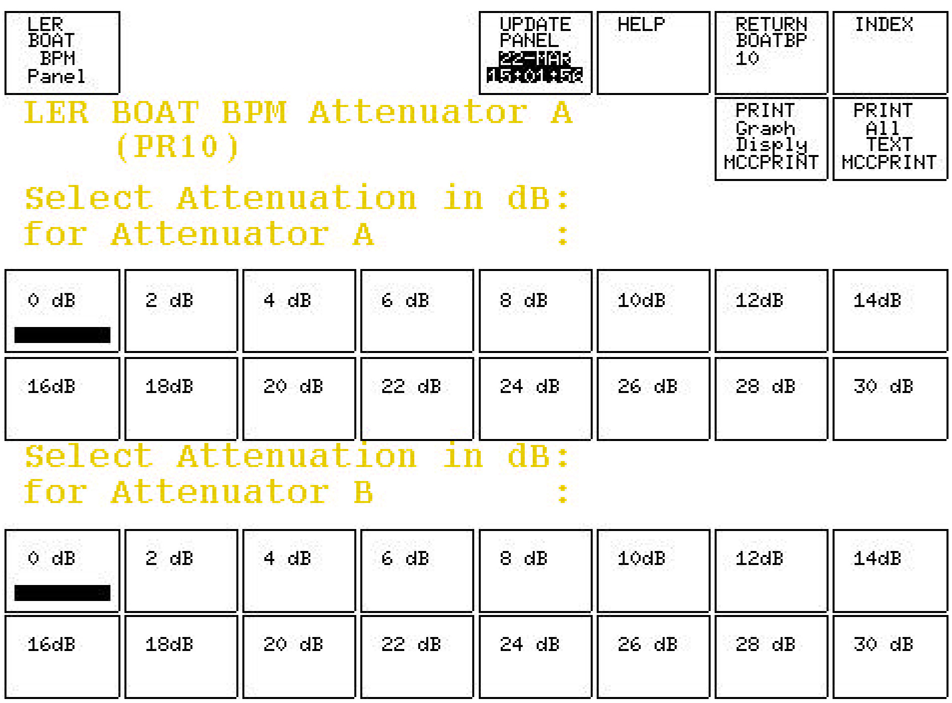

FIGURE 13. ***A*** **and** ***B*** **attenuators setup panel.**

To check the BOAT BPM analog status, select a “ BOAT BPM Analog” button, located at the top left of the BOAT BPM main panel. The status data appear on graphic display (Fig. 14).

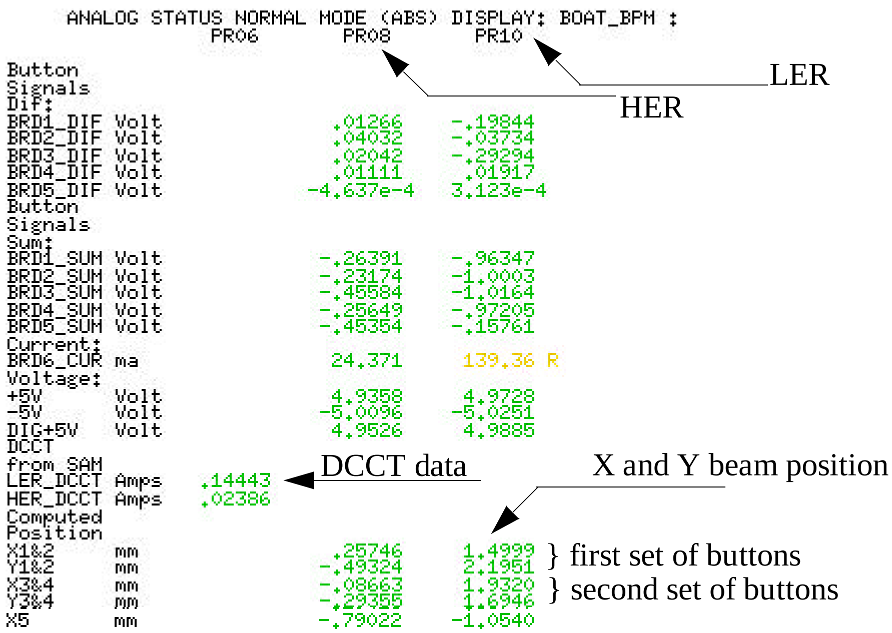

FIGURE 14. The BOAT BPM analog status panel, 144 mA beam.

The signals on the analog status panel are: logrf boards sum and difference signals, linrf board current signal, mother board power supply analog status: + 5 V, - 5 V and +5 V digital, LER and HER DCCT signals, computed *X* and *Y* beam positions. The data are updated every 20 seconds.

7.0 CHECK THE BOAT BPM STATUS.

During the normal operation, the trigger status should be " OK". The " Board 6 I" status should be " HIGH" if the beam current is higher than 100 mA, (Fig. 15).

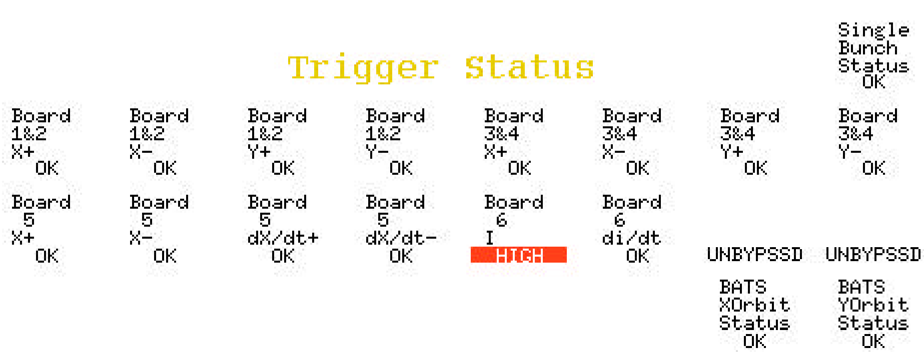

FIGURE 15. The trigger status. No trip, the beam current is higher than 100 mA.

The BATS status should be " OK" too. To check it, open BATS Panel (PR10 for LER). The *X* and *Y* orbit indicators (Fig. 16) are labeled " Orbit Change...", the *dI/dt* and *Single Bunch* trigger has label " dI/dt or Single Bunch". To check current status, open BATC panel (PR8 for LER). The current indicator label is " Current Limit", indicator should be in " TRIPPED" state if " Board 6 I" is " HIGH".

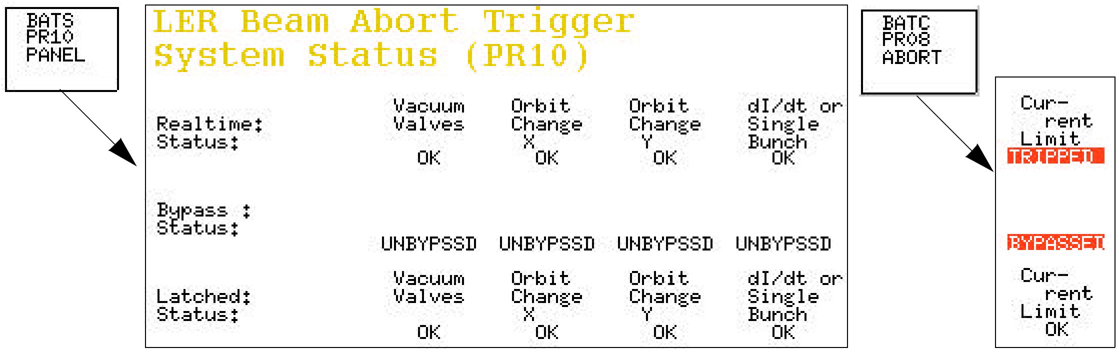

FIGURE 16. BAT S and C status. No trip, the beam current is higher than 100 mA.

If a trip is detected, the appropriate indicator should go from " OK" to " TRIP". The BATS status should go to " TRIP" too. After 1.5 or 2 minutes the BOAT's " TRIP" indicator status should be automatically reset to " OK", it could be reset manually, by clicking the " Reset" button (see 6.0, Fig. 12).

7.1 Check the beam position.

The beam position could be derived from the Buttons Signals data, displayed on the analog status panel.

X position is

$$X=((-DIFi)-(-DIFj))*k \text{ cm},$$

Y position is

$$Y=((-DIFi)+(-DIFj))*k \text{ cm},$$

where *i* and *j* are 1 and 3 or 2 and 4; *k* is normalization coefficient, $k = kc = 0.931$ for the circular beam pipe, $k = ke = 0.619$ for the elliptical one, the DIF signals are inverted. The LER first and third set and the HER first and second sets of buttons are located in a circular beam pipe, the LER second set is located in the elliptical beam pipe, HER third set is located in the octagonal chamber, normalization coefficient is *ke*.

For the dispersive region *X* position (cm) is

$$X5 = -DIF5*kc, \text{ LER}$$

$$X5 = -DIF5*ke, \text{ HER}$$

The calculated position should corresponds to the " Computed Position" *X1&2*, *Y1&2*, *X3&4*, *Y3&4* (*X5* position data will be added later).

If the module is disconnected, or trigger signal chain is broken, the module should be in a trip condition and should send a trigger to the BATS. The signal chain check is shown on Tab. 5.

The DIFF and SUM values depend on logrf boards offsets at the different beam currents and on the beam position. The maximum DIFF value could be 2.15 V at trip condition. It is equivalent to 2 cm *X* or *Y* beam position offset along the *U* or *V* axis toward button for 2.8 cm.

TABLE 6. DIFF and SUM check to verify the BOAT module connections to the buttons.

beam on center	**DIFF**	**SUM**
Cables are connected	LOW (up to hundreds mV)	HIGH, depends on current
One cable is disconnected	HIGH (above 3 V)	between HIGH and LOW
Two cables are disconnected	LOW (up to hundreds mV)	LOW

The H BOAT (HER BOAT BPM) test bench results are shown on table below (Tab. 7).

TABLE 7. The test bench DIFF and SUM measurements at simulated 1 A and 100 mA currents.

test bench	**|DIFF|, V**	**|SUM|, V**
current 1 Amp		
Cables are connected	0.04	1.44
One cable is disconnected	3.12	1.05
Two cables are disconnected	0.02	0.17
current 100 mA		
Cables are connected	0.01	0.81
One cable is disconnected	2.47	0.50
Two cables are disconnected	0.02	0.17

7.2 The beam current measurements.

The beam current, shown in Fig. 14 (part 6) is 139 mA for BRD6_CUR and 144 mA for the DCCT. The BOAT current measurements values are close to the DCCT measured current, about 4% less than the DCCT for currents around 100 mA (Fig. 14). The BRD6_CUR LER beam current versus DCCT current is shown below (Fig. 17). There is an initial offset, about 30 mA. The difference between the DCCT and BRD6_CUR at 100 mA is between 6% and 7%.

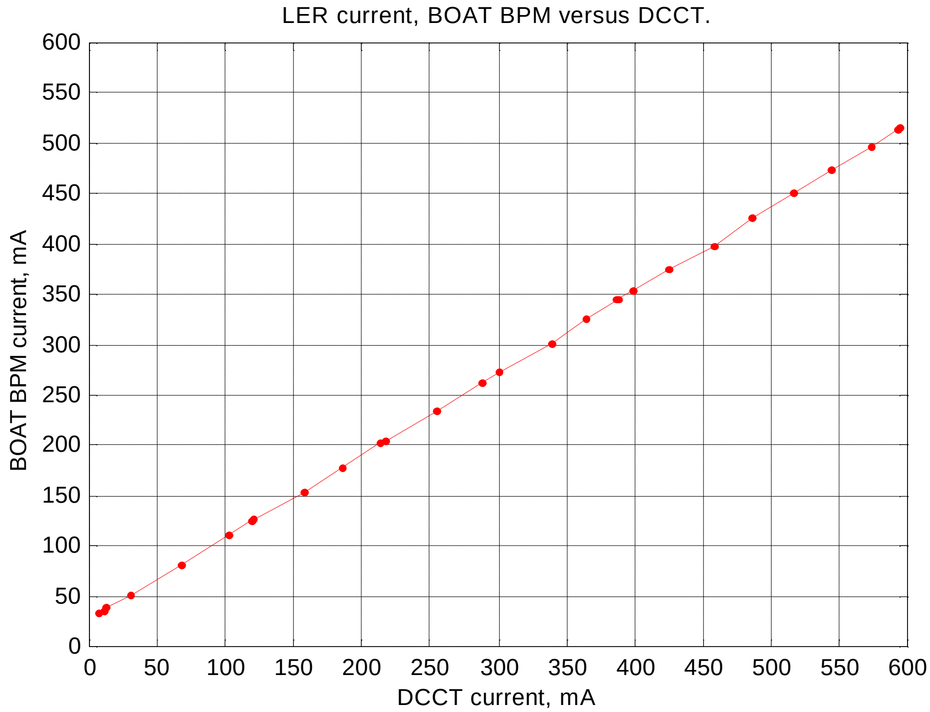

FIGURE 17. The LER BOAT BPM current versus DCCT current.

To check current readings on line, use the history plot and compare the BOAT BPM current with the DCCT data (Fig. 18).

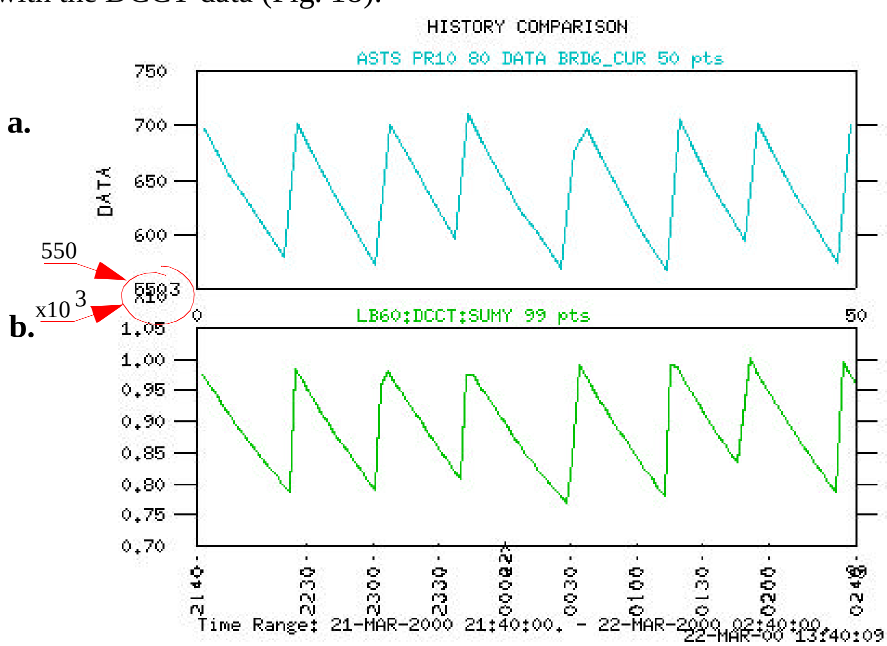

FIGURE 18. The current versus time. BOAT BRD6_CUR, mA - a, DCCT, mA - b (data x 103).**

To compare data, plot A/B function, where A and B are BOAT and DCCT data respectively (Fig 19).

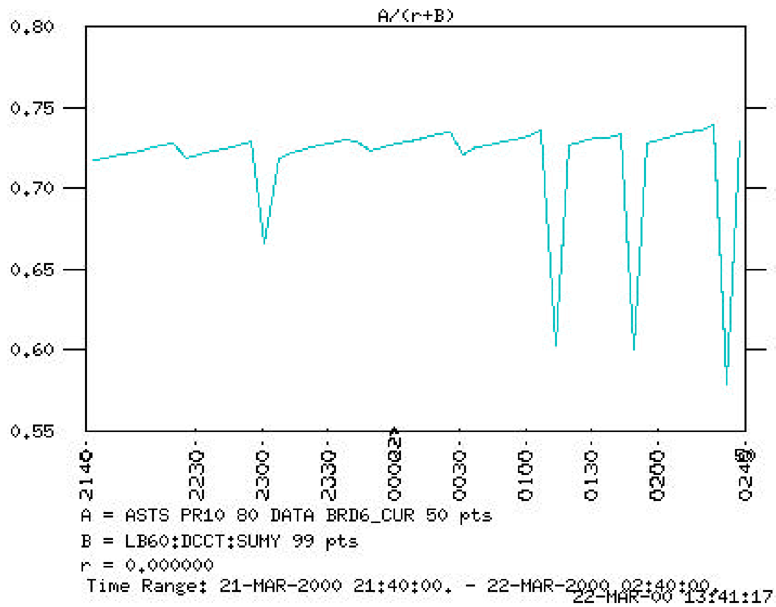

FIGURE 19. The ratio BOAT BRD6_CUR / DCCT versus time, same scale as above.

The beam current is 900 mA, far above 100 mA. At DCCT current 970 mA, the BOAT current is about 700 mA. The average ratio is about 0.72, so the difference is 28%.

The same ratio is shown on Fig. 20, for a 30 minutes time interval. The ratio is between 0.72 and 0.74.

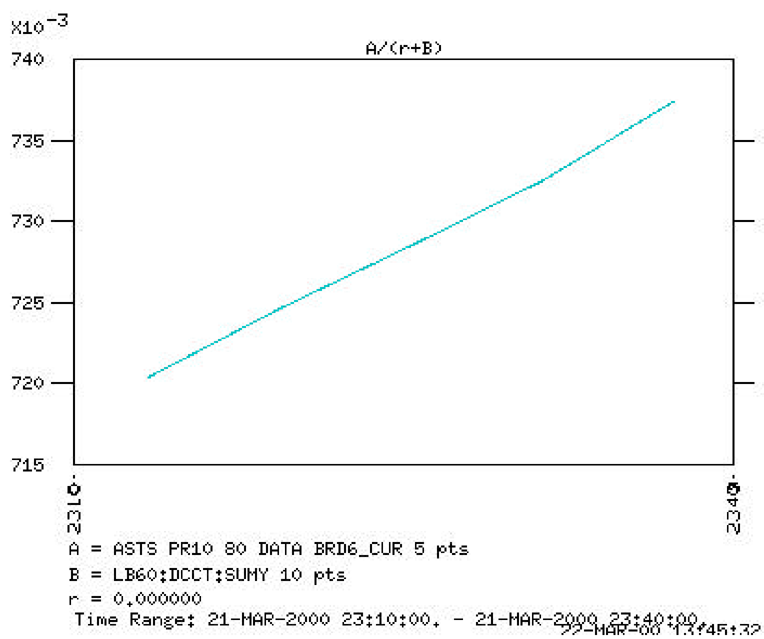

FIGURE 20. The ratio BRD6_CUR / DCCT versus time, 30 minutes time scale.

8.0 Checking BOAT trip.

The following Errorlog syntax will find the time/cause of all beam aborts:

- SET/STRING=(BATS,SUBMIT,LATCH)/MATCH=AND

and the following syntax will find the time of Beam Aborts caused by dI/dt:

- SET/STRING=(BATS,SUBMIT,LATCH,dI)/MATCH=AND

The time qualifiers SINCE and BEFORE can be used to limit your search.

Below is an example of the trip caused by dI/dt :

- 1-SEP-2000 19:27:23 %SIP-W-ACTION, V040 SIPMAIN - HER_BATS SUBMITTED! 1927 PR08 HERdI/dt LATCHED LATCHED

The message must contain “LATCHED” in it to be correct, otherwise ignore it.

TABLE 8. The BOAT BPM Errorlog syntax.

board 1&2	**board 3&4**	**board 5**	**dX/dt**	**dI/dt**	**Single Bunch**
B1_2X+	B3_4X+	B5X+	B5DX_DT+	B6DI_DT	SNGLBNCH
B1_2X-	B3_4X-	B5X-	B5DX_DT-		
B1_2Y+	B3_4Y+				
B1_2Y-	B3_4Y-				

a. *

```
19-SEP-2000 12:13:17  %SIP-E-ERRMSG,        V040  SIPMAIN - BATS,PR10,  15,LERdI
/dt&Sng,LATCHED ,LATCHED ,ERROR    ,     ,
19-SEP-2000 12:13:17  %SIP-W-ACTION,        V040  SIPMAIN - LER_BATS SUBMITTED!
1213 PR10 LERdI/dt LATCHED  LATCHED
```

b.

```
19-SEP-2000 12:13:27  %SIP-E-ERRMSG,        V040  SIPMAIN - MISC,PR10,  11,BOAT
BPM     ,SNGLBNCH,TRIP     ,ERROR    ,     ,$MPS
```

c.

```
19-SEP-2000 13:12:11  %SIP-E-ERRMSG,        V040  SIPMAIN - MISC,PR08,  11,BOAT
BPM     ,B6DI_DT ,TRIP     ,ERROR    ,     ,$MPS
```

*SIP - Summary Information Process

FIGURE 21. ERRLOG messages; a. BATS error - latched dI/dt&Single Bunch trigger, action - tripped beam; b. trigger source - BOAT, Single Bunch, LER; c. trigger source - BOAT dI/dt message, HER.

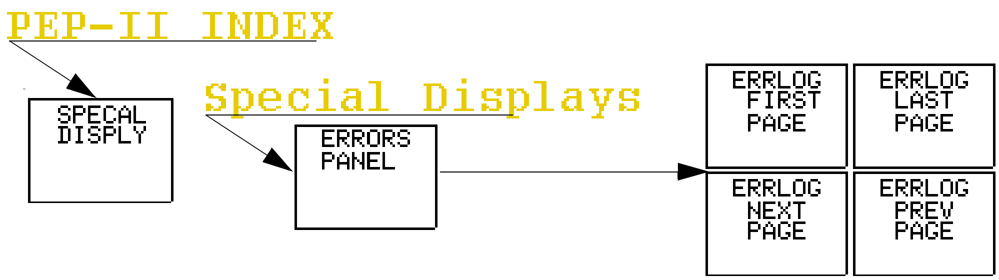

FIGURE 22. The path to the "On line" error messages.

9.0 TEST PROCEDURE.

All tests must be performed without beam. After tests, the module must be RESET to be able to monitor beam.

Before the test, be sure there is no beam and beam is not being injected. Use Beam Injection Control panel to check the beam status (Fig. 21).

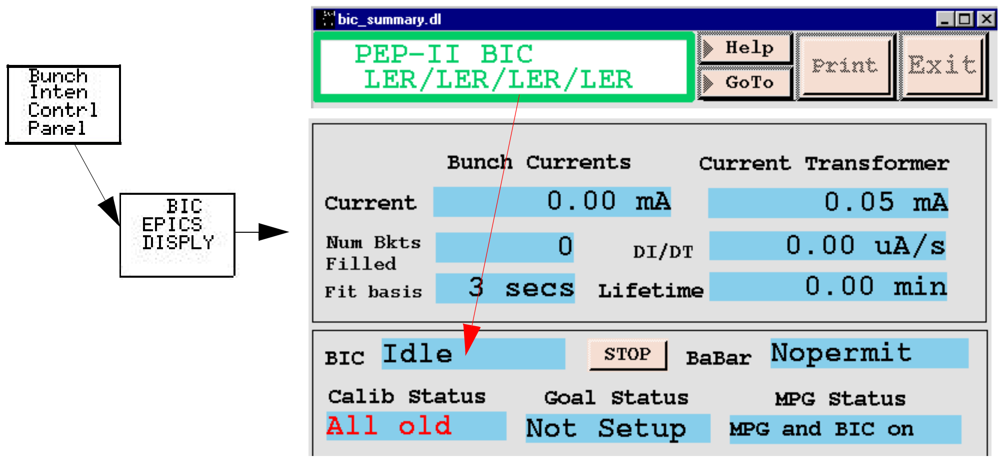

FIGURE 23. The Beam injection control display.

If BIC state is " Idle", Current Transformer " DCCT-Ped" reads 0 mA (0.00XXX) it is safe to perform tests.

9.1 X and Y beam position offset simulation and trigger status test.

To perform the test, follow the instructions below (Fig. 24).
1. Select test to start from, for example “ Select 1&2 Xt”.
2. Push “ GO” button. The boards 1 and 2 are selected. X test is set.
3. Select “ Setup attenuation panel”.
4. Set A attenuator to 8 dB, B to 0 dB.
5. Return to the BOAT panel: click on “ ... BOAT BPM Panel”.
6. Check 1&2X+ and 1&2X- trigger status and write it to a test table (Tab. 10, LER; Tab. 11, HER).
7. On the BOAT panel, check attenuators status.
8. Click “ ANALOG STATUS DIAG” button.
9. Check BRD1_DIF and BRD2_DIF data and write them to a test table.
10. Go back to attenuators panel.
11. Set A attenuator to 10 dB.
12. Repeat steps 5 to 9.
13. Set A attenuator to 12 dB.
14. Repeat steps 5 to 9.
Test is completed.
15. Click “ Reset” button

In this test the “ Board 1&2 X-” status indicator should go to a trip state at 10 dB or 12 dB attenuation. See an example below (Fig. 22).

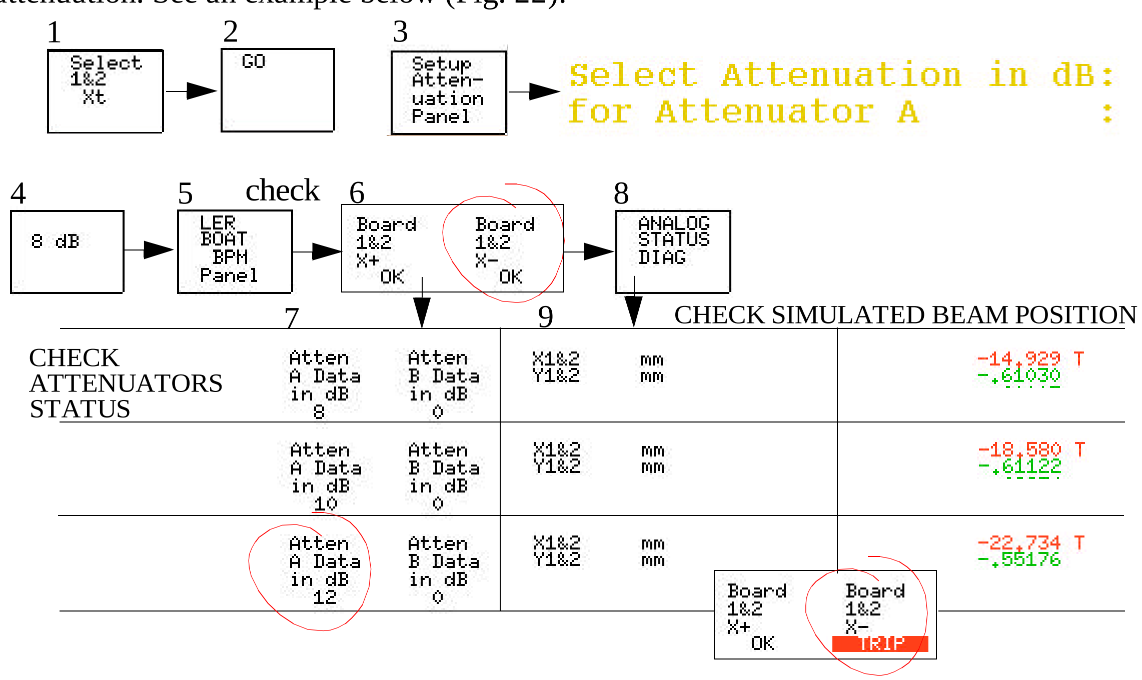

FIGURE 24. An example of the X position offset simulation and trigger status test.

To complete all tests, follow to the steps in the Test Tables Tab. 10 and Tab. 11, see calibration examples in Tab. 12 and Tab 13 (in the attachment).

Calculated *X* and *Y* position offsets at 8 dB, 10 dB and 12 dB attenuations are +-14.7 mm, +-18.4 mm and +-22 mm respectively. The “ delta” |Δ| on the Test Table is the difference between calculated (Pcalc) and measured (Pmsr) position,

$$|\Delta|=|Pcalc-Pmsr|.$$

According to the requirements (4.0, 8) the “ delta” should be in a range +- 2 mm.

By monitoring trigger, position and threshold signals from the BOAT BPM module front panel, it can be determined, that at 8 dB attenuation, the signal is approximately 1.47 V +- small offset. Between 10 dB and 12 dB attenuation (1.84V and 2.2 V respectively) the threshold level should be crossed and the trigger signal should change state.

There should never be a trigger at 8 dB attenuation or less, there should always be a trigger at 12 dB attenuation or more. Due to individual logrf boards offset, the trigger signal could trip at 10 dB attenuation.

9.2 “ Select board” test.

The “ Select board” is a single daughter board functionality test. A daughter boards 5 and 6 tests include *dX/dt* and *dI/dt* tests respectively. Test procedure is the same as in part 6.1.

First, set attenuators to A = B = 0 dB. “ Buttons Signals Difference” and “ Buttons Signals Sum” appear on “ Analog Status” panel (Fig. 10). The DIF signal should be from 0V to +-0.19 V, the SUM should be between -1.4 V and -1.6 V, depending on the board offset. To simulate different offsets, step A attenuation from 30 dB to 0 dB with B = 0 dB, then with A = 0 dB step B from 0 dB to 30 dB. The suggested step is 6 dB, starting from 0 dB attenuation. The monitored “ difference” and “ sum” signal are inverted. The measured values should be symmetrical to one at A=B=0 dB in the range between +- 3.5 V (Fig. 15). The SUM value should be maximal at A=B=0 dB.

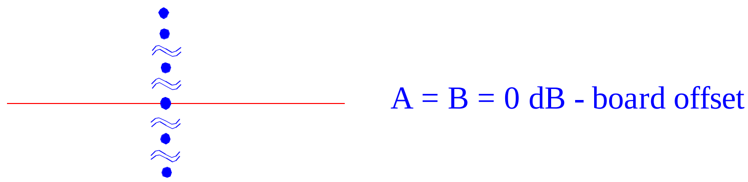

FIGURE 25. “ Buttons Signals Difference” values distribution at different test signal attenuation.

The “ Current” data (if board 6 is selected) maximum value should be observed at A = B = 0 dB.

When testing the board 6, the Current (“ Board 6 I”) trigger status “high” state means beam current is > 100 mA, Low state - beam current is < 100 mA. The *dI/dt* trigger status changes state to “ trip” if a current drop equivalent to 20 mA or more is simulated. See part 6.1.

9.3 RESET.

WARNING: Do not forget to RESET module after the test.

After RESET, module is ready to monitor beam or to proceed to another test.

10.0 TEST SOFTWARE CODE.

IDOM - 16 channels:

4 bits - [0 to 3], [*] - * bit number
    1111 / 0000 Reset, pulse type
    0001 select board 1
    0010 select board 2
    0011 select board 3
    0100 select board 4
    0101 select board 5
    0110 select board 6
    1000 select boards 1&2; X test
    1001 select boards 1&2; Y test
    1010 select boards 3&4; X test
    1011 select boards 3&4; Y test
4 bits - [4 to 7] Attenuator A data
4 bits - [8 to 11] Attenuator B data
4 bits - spare

IDIM - 16 channels:

14 bits - trigger status
    boards 1&2
    X+ [0]
    X- [1]
    Y+ [2]
    Y- [3]
    boards 3&4
    X+ [4]
    X- [5]
    Y+ [6]
    Y- [7]
    board 5
    X+ [8]
    X- [9]
    dX/dT+ [10]
    dX/dT- [11]
    board 6
    I (current trig. status) [12]
    dI/dT [13]
    Single Bunch [14]
1 bit - spare

SAM - 16 channels:

boards 1 to 5
    sum [inputs A1-A10], channels [0 - 4]
    difference [inputs B1 - B10], channels [6 - 10]

board 6

current [inputs B11 and B12], channel [11]

spare

channel [5] spare [A11, A12]

channel [12] free [C1, C2]

power status

channel [13] +5 V analog [C3, C4]

channel [14] -5 V analog [C5, C6]

channel [15] +5 V digital [C7, C8]

11.0 MAINTENANCE.

Every month (or more often) maintenance recommendations: to calibrate LER and HER BOAT BPM; to check trip thresholds; to check that BATS bypass trigger status is "UNBYPSSD" (Orbit Change X, Orbit Change Y, dI/dt or Single Bunch, Current Limit) . In the case of the BOAT BPM module malfunction, replace it with the Maintenance BOAT BPM module (MBOAT).

11.1 Maintenance BOAT BPM module modifications for LER or HER.

11.1.1 Mother board modifications.

The MBOAT module mother board is assembled to use for LER. To modify it for HER, the resistors R4, R5, R6, R116 should be replaced according to the schematic. The values are shown below (Tab. 1).

TABLE 9. BOAT BPM mother board resistors values for LER and HER modules.

Resistor reference designator	Resistor value for LER, Ω	Resistor value for HER, Ω
R4	619	931
R5	619	931
R6	619	931
R116	931	619

11.1.2 Additional modifications

Before the replacement of the malfunctioning module with the MBOAT module, insert the daughter boards (from the malfunctioning module) in the corresponding MBOAT mother board slots. If one of the daughter boards is broken, replace it with spare one.

To replace the linear RF daughter board, modify the gain of the spare one according to the schematic.

The “Single Bunch” shelf should be disconnected from the malfunctioning module, installed on the MBOAT module, connected to the input cables and to the mother board as it was in the malfunctioning module (according to the Single Bunch installation diagram and schematic).

Take replaced module to test bench. Test it with LabView program, use file: **boat_test3.vi**.

12.0 CONCLUSION.

The BOAT BPM concept, functionality and location are described in chapter 1. Chapters 2, 3 and 4 have brief introductions to logrf, linrf, Single Bunch and mother boards. Descriptions which help to understand the software interface, to check the BOAT BPM status and to perform test procedure are in chapters 6, 7 and 8. The requirements, chapter 5, is squeezed between the hardware and software parts. Chapters 9 10 and 11 are Test procedure, Test Software Code and Maintenance respectively.

Attachment - Test Tables.

REFERENCES.

[1] SAM, IDOM, IDIM modules - www.slac.stanford.edu/grp/cd/soft/wwwman/hard.www/

medvedko@slac.stanford.edu

ATTACHMENT.

TABLE 10. LER BOAT BPM Test table.

	Att. A, dB	Att. B, dB	position, mm	X +	X -	Y +	Y -	measured pstn, mm	|Δ|, mm
B1&2Xt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B1&2Yt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B3&4Xt	8	0	-9.8						
	10	0	-12.2						
	12	0	-14.7						
	0	8	9.8						
	0	10	12.2						
	0	12	14.7						
B3&4Yt	8	0	-9.8						
	10	0	-12.2						
	12	0	-14.7						
	0	8	9.8						
	0	10	12.2						
	0	12	14.7						
B6 I, mA	28	28	80						
B6 I, mA	26	26	106						
B6 dI/dt, mA	22/24	22/24	160/130						
B5 dX/dt-	0/12	0	0/-10.99						
B5 dX/dt+	12/0	0	-10.99/0						
B5 dX/dt-	0	12/0	10.99/0						
B5 dX/dt+	0	0/12	0/10.99						
B5 X5	18	0	-16.49						
	20	0	-18.32						
	22	0	-20.15						
	0	18	16.49						
	0	20	18.32						
	0	22	20.15						

TABLE 11. HER BOAT BPM Test table.

	Att. A, dB	Att. B, dB	position, mm	X +	X -	Y +	Y -	measured pstn, mm	|Δ|, mm
B1&2Xt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B1&2Yt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B3&4Xt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B3&4Yt	8	0	-14.7						
	10	0	-18.4						
	12	0	-22						
	0	8	+14.7						
	0	10	+18.4						
	0	12	+22						
B6 I, mA	30	30	151						
B6 I, mA	26	26	223						
B6 dI/dt, mA	22/24	22/24	330/271						
B5 dX/dt-	0/18	0	0/-12						
B5 dX/dt+	18/0	0	-12/0						
B5 dX/dt-	0	18/0	11/-0.5						
B5 dX/dt+	0	0/16	-0.5/9.6						
B5 X5	20	0	-12.21						
	22	0	-13.43						
	24	0	-14.65						
	0	20	12.21						
	0	22	13.43						
	0	24	14.65						

TABLE 12. LER BOAT BPM Test table.

	Att. A, dB	Att. B, dB	position, mm	X +	X -	Y +	Y -	measured pstn, mm	|Δ|, mm
B1&2Xt	8	0	-14.7		-			-15.07	0.37
	10	0	-18.4		-			-18.9	0.5
	12	0	-22		T			-23.07	1.07
	0	8	+14.7	-				14.75	0.05
	0	10	+18.4	-				18.39	0.01
	0	12	+22	T				22.39	0.39
B1&2Yt	8	0	-14.7				-	-14.97	0.27
	10	0	-18.4				-	-18.64	0.24
	12	0	-22				T	-22.67	0.67
	0	8	+14.7			-		14.92	0.22
	0	10	+18.4			-		18.69	0.29
	0	12	+22			T		22.81	0.81
B3&4Xt	8	0	-9.8					-11.03	1.23
	10	0	-12.2		T			-13.52	1.32
	12	0	-14.7		T			-16.24	1.54
	0	8	9.8	-				9.12	0.68
	0	10	12.2	-				11.55	0.65
	0	12	14.7	T				14.19	0.51
B3&4Yt	8	0	-9.8				-	-9.72	0.08
	10	0	-12.2				-	-12.21	0.01
	12	0	-14.7				T	-14.88	0.18
	0	8	9.8			-		10.44	0.64
	0	10	12.2			-		12.86	0.66
	0	12	14.7			T		15.53	0.83
B6 I, mA	28	28	80	L				84	
B6 I, mA	26	26	106	H				106	
B6 dI/dt, mA	22/24	22/24	160/130	T				163/132	
B5 dX/dt-	0/12	0	0/-10.99		T			-11.95	
B5 dX/dt+	12/0	0	-10.99/0	T				-0.47	
B5 dX/dt-	0	12/0	10.99/0		T			-0.47	
B5 dX/dt+	0	0/12	0/10.99	T				10.14	
B5 X5	18	0	-16.49		-			-17.67	1.18
	20	0	-18.32		T			-19.63	1.31
	22	0	-20.15		T			-21.39	1.24
	0	18	16.49	-				15.22	1.27
	0	20	18.32	-				16.85	1.47
	0	22	20.15	T				18.18	1.97

TABLE 13. HER BOAT BPM Test table.

	Att. A, dB	Att. B, dB	position, mm	X +	X -	Y +	Y -	measured pstn, mm	|Δ|, mm
B1&2Xt	8	0	-14.7		-			-14.71	0.1
	10	0	-18.4		-			-18.29	0.11
	12	0	-22		T			-22.35	0.35
	0	8	+14.7	-				15.65	0.95
	0	10	+18.4	-				19.28	0.88
	0	12	+22	T				23.29	1.29
B1&2Yt	8	0	-14.7				-	-14.11	0.59
	10	0	-18.4				-	-17.73	0.67
	12	0	-22				T	-21.69	1.69
	0	8	+14.7			-		16.23	1.53
	0	10	+18.4			-		19.91	1.51
	0	12	+22			T		23.96	1.96
B3&4Xt	8	0	-14.7		-			-14.85	0.15
	10	0	-18.4		-			-18.39	0.1
	12	0	-22		T			-22.35	0.35
	0	8	+14.7	-				15.31	0.61
	0	10	+18.4	-				18.95	0.55
	0	12	+22	T				23.00	1.0
B3&4Yt	8	0	-14.7				-	-15.16	0.46
	10	0	-18.4				-	-18.75	0.35
	12	0	-22				T	-22.74	0.74
	0	8	+14.7			-		15.00	0.3
	0	10	+18.4			-		18.58	0.18
	0	12	+22			T		22.61	0.61
B6 I, mA	30	30	151	H				143	
B6 I, mA	26	26	223	H				221	
B6 dI/dt, mA	22/24	22/24	330/271	T				337/ 273	
B5 dX/dt-	0/18	0	0/-12		T			-0.47	
B5 dX/dt+	18/0	0	-12/0	T				-11.83	
B5 dX/dt-	0	18/0	11/-0.5		T			10.65	
B5 dX/dt+	0	0/18	-0.5/11	T				-0.47	
B5 X5	20	0	-12.21		-			-13.13	0.92
	22	0	-13.43		T			-14.23	0.8
	24	0	-14.65		T			-15.46	0.81
	0	20	12.21	-				11.96	0.25
	0	22	13.43	-				13.06	0.37
	0	24	14.65	T				14.21	0.44