PSB RF bypasses
+ PSB TFB electronics

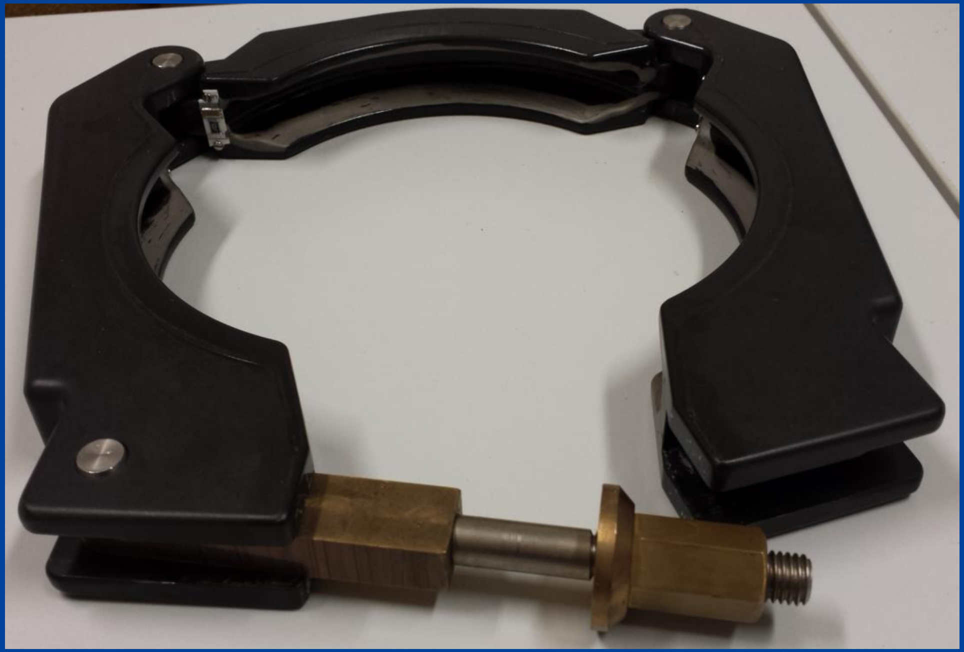
Executive summary:

Components for the PSB rf-bypasses will be installed (Joao BENTO) on the 15 th of June 2015 in the PS to be tested with beam currents equivalent to those expected in the PSB with Linac 4.

The new electronic circuits for the PSB TFB have been produced and their firmware is starting the testing phase.
Delivery expected in October 2015.

The delivery of power amplifiers (800 W instead of 100 W) foreseen for mid 2016 is a source of worry. A rf management meeting should be held soon to address this issue.

PSB RF bypasses
Presently installed hardware

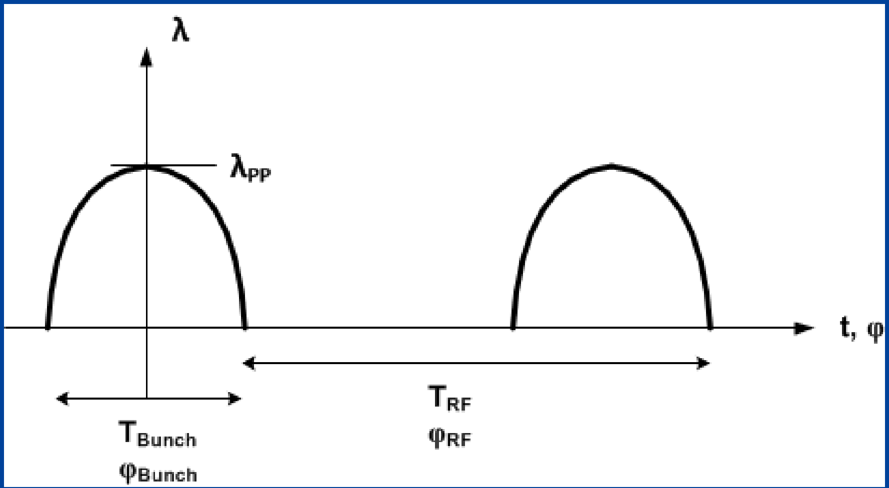


3 times
0.5Ω /1 W
in series with
4 x // 100nF

PSB RF bypasses
Presently installed hardware

0.5Ω /1 W from Vishay dale 6.5 x 3.2 x 0.4 mm
No detailed specifications found

The rf bypasses have to stand 48 A_p



The Max peak beam intensity will be considered with 2.5E13 ppb and 130 ns bunch length

$$I_{beam\ peak\ Linac\ 4\ at\ ej} = \lambda_{pp\ ej} = \frac{\pi}{2} \cdot \frac{Q_{Bunch}}{T_{Bunch}} = \frac{3.14 \cdot 2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{260 \cdot 10^{-9}} = 48 A_p$$

For Linac 4 we need a

0.5 Ω resistor

0.5 W in continuous mode

1150 W in pulsed mode (48A_p and 24 V_p)

Dimensions compatible with present setup

PSB RF bypasses
Beam current with Linac 2

Our experience with the bypasses installed since 2000 goes as follow:

Max beam intensity considered with Linac 2:
1E13 ppb and 130 ns bunch length

$$I_{Beam\ peak\ Linac2} = 19A_{\text{p}}$$

Peak power in a (single) 0.5 Ω resistor = 184 W_p
Peak power in a 0.5 Ω resistor when the beam current is shared = 20 W_p

Peak voltage across the resistance = 9.5V_p

The specifications of the resistor being used were not found.
We only know they are 0.5 Ω and 1 W

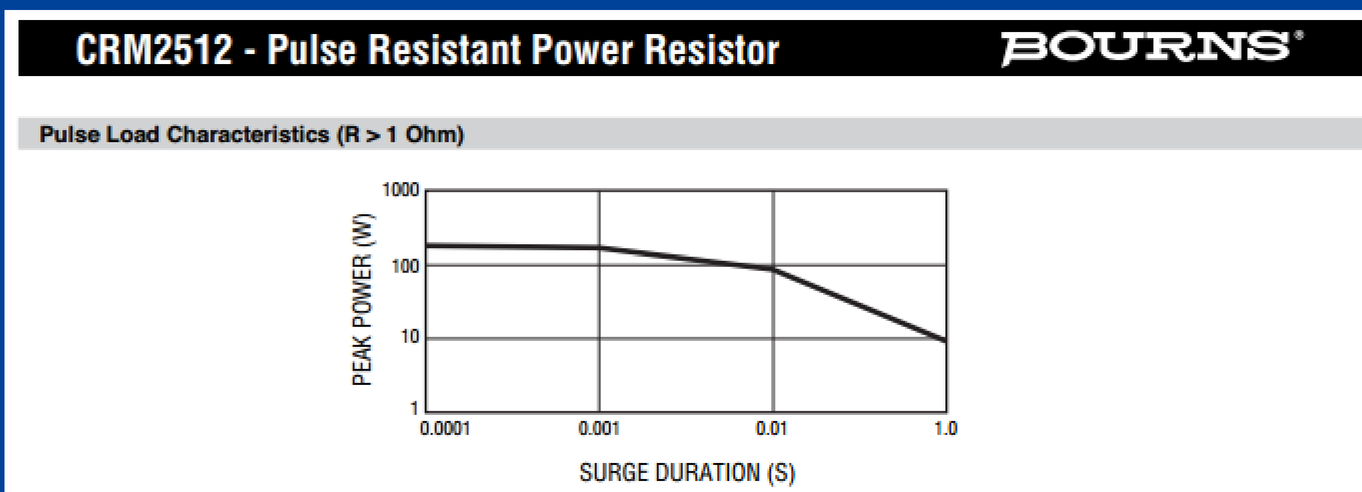
The peak power in the present resistors has been in between 20 and 180 times higher than the nominal value.

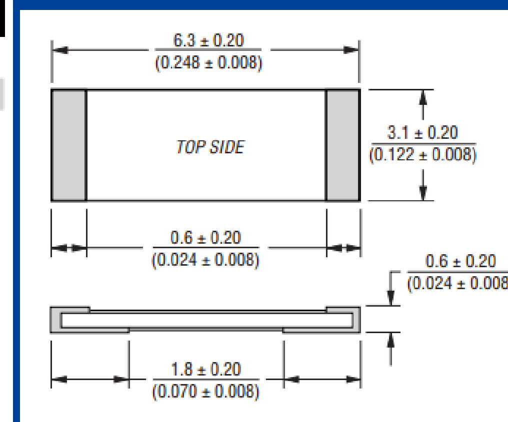
PSB RF bypasses
Specifications of resistors

The 1 W resistors in place have dealt with a peak power between 20 and 180 W.

For a very few resistors on the market, the power overhead is specified:

http://www.bourns.com/data/global/pdfs/CRM.pdf





The CRM2512 has a nominal power rating of 2 W at 70°

In this example a 2W resistor can stand a 150 W pulse of 1ms

This model is under-specified for a use with Linac 4

PSB RF bypasses
Selected resistor

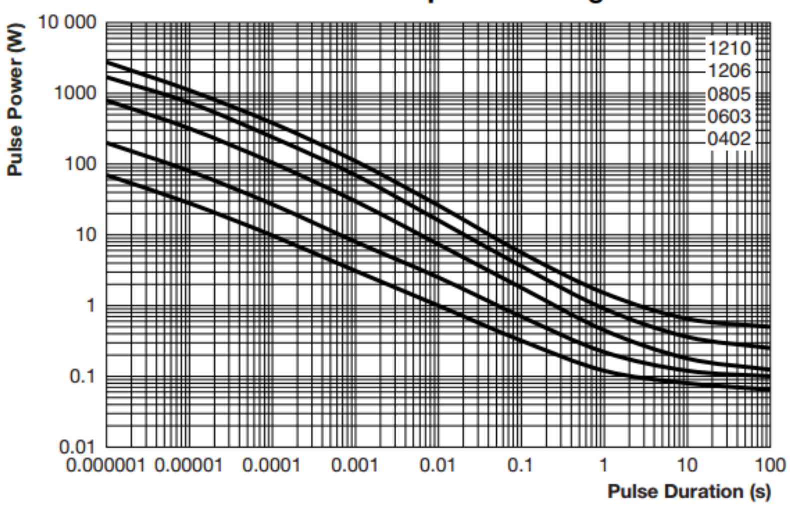
VISHAY. www.vishay.com/docs/20024/dcrcife3.pdf **D/CRCW-IF e3**

Vishay

Pulse Proof Thick Film Chip Resistors

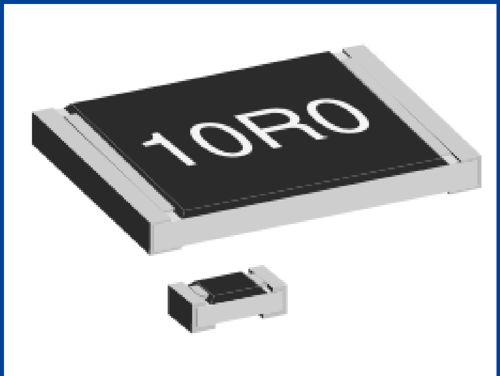
STANDARD ELECTRICAL SPECIFICATIONS								
MODEL	CASE SIZE	SIZE METRIC	POWER RATING $P_{70\ °C}$ W	LIMITING ELEMENT VOLTAGE $U_{max.}$ AC/DC	TEMPERATURE COEFFICIENT ppm/K	TOLERANCE %	RESISTANCE RANGE Ω	SERIES
CRCW1210-IF	1210	RR 3225M	0.50	200	± 200	± 5, ± 10	1R0 to 100K	E24

Maximum pulse dissipation as a function of the pulse duration, continuous pulse loading



Maximum pulse load, continuous pulses; applicable if $\bar{P} \le P(\vartheta_{amb})$ and $\hat{U} \le \hat{U}_{max.}$;
for permissible resistance change equivalent to 8000 h operation

This resistor can stand 3000 W during 1 us (1150 W required)
Factor 6000 with respect to its CW specs



PSB RF bypasses
Selected resistor

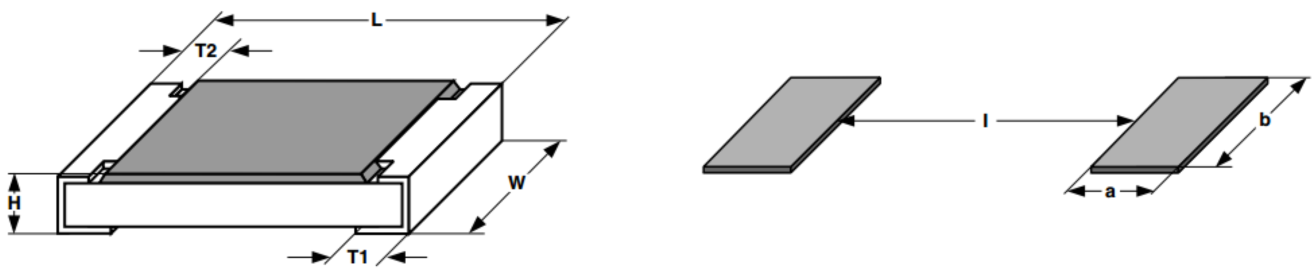
VISHAY

www.vishay.com/docs/20024/dcrcife3.pdf **D/CRCW-IF e3**

Vishay

Pulse Proof Thick Film Chip Resistors

DIMENSIONS



SIZE		DIMENSIONS in millimeters					SOLDER PAD DIMENSIONS in millimeters					
							REFLOW SOLDERING			WAVE SOLDERING		
INCH	METRIC	L	W	H	T1	T2	a	b	l	a	b	l
1210	3225	3.2 ± 0.2	2.5 ± 0.2	0.55 ± 0.05	0.45 ± 0.2	0.4 ± 0.2	0.9	2.5	2.0	1.1	2.5	2.2

The length of this resistor (3.2x2.5x0.45mm) is half of the one used at present (6.5x3.2x0.42 mm)… so is the power (0.5 W instead of 1W)

PSB RF bypasses
Selected resistor

VISHAY

www.vishay.com/docs/20043/crcwhpe3.pdf

www.vishay.com

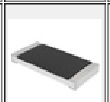
CRCW-HP e3

Vishay Draloric

Pulse Proof, High Power Thick Film Chip Resistors

Acheter l'article sélectionné | Comparer la sélection | Comparez jusqu'à 20 articles.

Sélectionner	Image	Référence Mouser	Fab. Numéro de référence	Fab.	Description		Disponibilité	Prix (CHF)	Quantité	RoHS
☐	 Agrandir	71-CRCW25121R00JNEGH Pour passer une commande complète de bobine, commandez par multiples de 2000 :	CRCW25121R00JNEGHP	Vishay / Dale	Résistances à couches épaisses - CMS 1.5watts 1ohms 5% 200ppm High Power En savoir plus	Fiche technique	5'765 En stock	**Bande coupée** 1: fr. 1.70 10: fr. 0.922 100: fr. 0.528 1'000: fr. 0.371 **Bobine** 2'000: fr. 0.354 10'000: Afficher **MouseReel disponible**	Acheter Min. : 1 Mult. : 1 **Bobine**: ***2'000***	RoHS Détails

Image	Référence Digi-Key	Référence fabricant	Fabricant	Description	Quantité disponible	Prix unitaire EUR	La quantité minimum à commander est de	Conditionnement	Série	Résistance (Ohms)	Tolérance	Puissance (Watts)
	541-1.00RTR-ND	CRCW25121R00FKEGHP	Vishay Dale	RES 1.00 OHM 1.5W 1% 2512 SMD	20,000 - Immédiatement	0.37735	2,000	Bande et bobine Emballage Alternatif	CRCW-HP	1	±1%	1,5W
	541-1.00RCT-ND	CRCW25121R00FKEGHP	Vishay Dale	RES 1.00 OHM 1.5W 1% 2512 SMD	20,351 - Immédiatement	1.77400	10	Bande coupée (CT) Emballage Alternatif	CRCW-HP	1	±1%	1,5W

PSB RF bypasses
Selected resistor

Replacing the present 0.5 Ω / 1W resistor which has resisted

$20\ W < P_{PEAK} < 184\ W$

by

2 resistors CRCW-HP e3 1 Ω /1.5 W in parallel (= 0.5 Ω / 3W)

resisting

$P_{Peak\ max} = 4000\ W\ (= 2000 + 2000)$

Should allow for a factor 3.5 margin for the peak power

and a factor 6 for the average power

PSB RF bypasses
Test in the PS

100 A_p beam current available in the PS

50 A_p beam current expected in the PSB

The new 2000 W_P CRCW-HP e3 resistors
may be tested in the PS

The PS rf bypasses are designed with 1 Ω resistor
withstanding 100 A (10 kW peak)

We will use 4 test resistors of 1 Ω assembled so as to get 1 Ω in total

PSB RF bypasses
Test in the PS

Ready for an installation in the PS
on the 15th of June 2015

PSB RF bypasses
Test in the PS

This is the first test bypass mounted is PS SS00 just after LS2 !

The resistors are NOT burnt! Only the soldering has melted!?

It has been found that the corresponding vacuum flange was in short-circuit

This means that the bypass was in parallel with a short-circuit!

What occurred ?????

PSB TFB electronics

C0

Output to power amplifiers

Blow-up excitation OASIS

Δ PU 4L5

Tune excitation

Blow-up excitation

PSB h1

PSB h1 OASIS

Tune excitation OASIS

PSB h64

Tune value CVORB

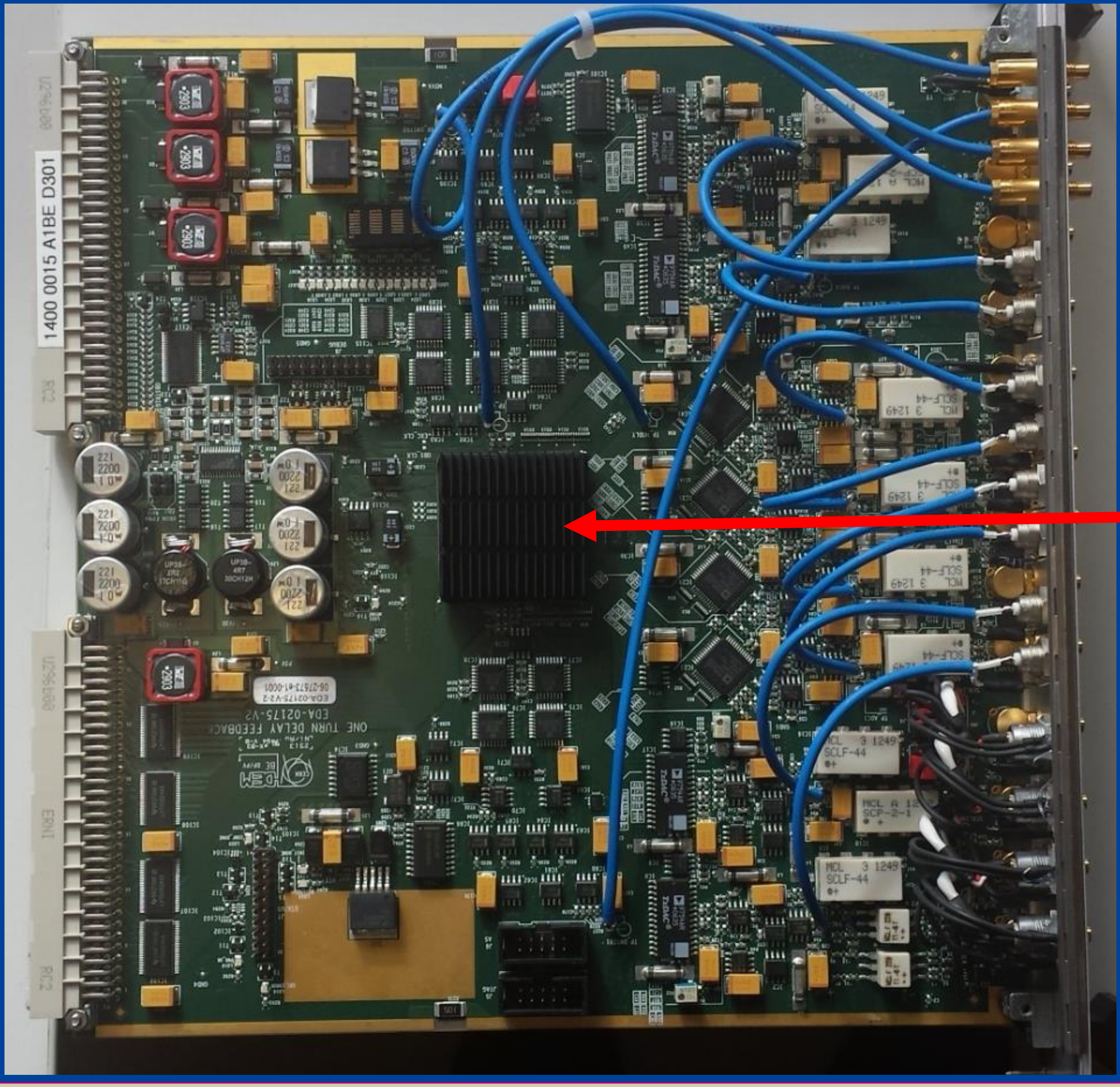
TFB loop Gain CVORB

Betatron phase CVORB

PU Δ 4L5 OASIS

PSB h64 clock OASIS

PSB TFB electronics



Board designed by D. Perrelet,

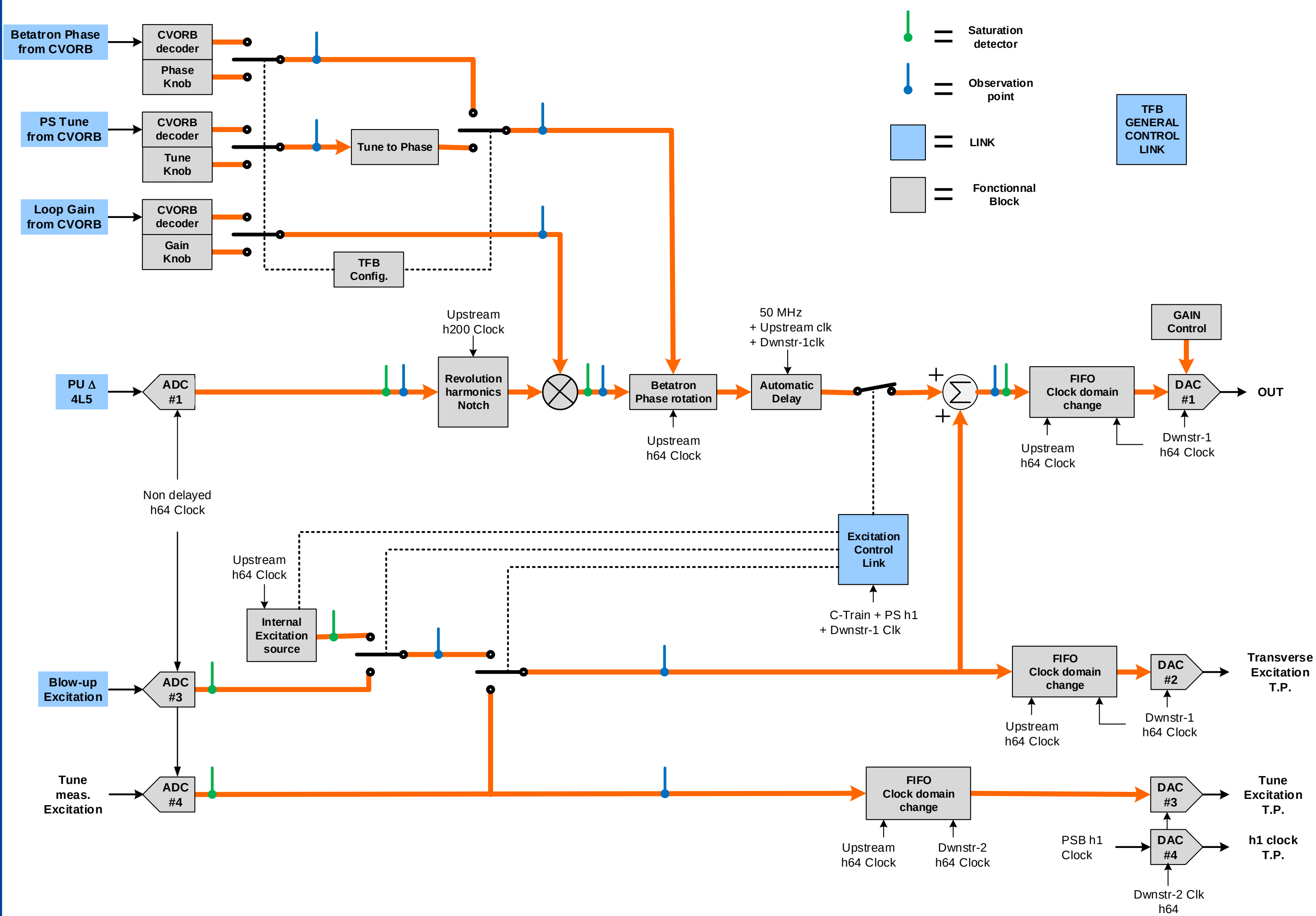
3rd iteration of a board initially designed by V. Rossi and first upgraded by M. Schokker

FPGA (Altera Stratix 2) to be programmed. 1020 pins

Issues being faced:
chip too loaded to deal with the 120 MHz clock at Ej.

PSB TFB electronics Firmware

PSB TFB Digital Signal Processing



PSB TFB electronics
Conclusion

Test in the PS of the new resistors to be used for PSB rf-bypasses from the 15th of June 2015 onwards

New low-level electronic circuits to be delivered in October 2015.

800 W power amplifiers progress is an issue requiring extraordinary measures.

Not mentioned in the presentation:

Tune value on a CVORB required for the operation of the new electronics

Spare PU in the ring would be a good investment (instead of unused longitudinal PUs)

Thank you!

Appendix

http://cds.cern.ch/record/447073/files/ps-2000-025.pdf

REDUCTION OF THE IMPEDANCE CREATED BY THE INSULATED VACUUM FLANGES IN THE PS BOOSTER

A. Blas, M. Chanel, C. Carli, C. Lacroix

http://cds.cern.ch/record/960437/files/cer-002626722.pdf

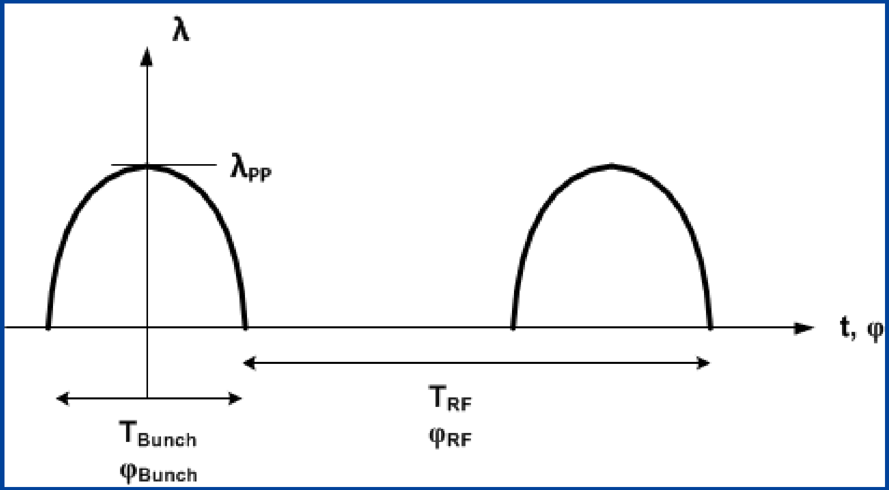
Coupling Impedance Measurements with the Coaxial Wire Method on the CPS RF Bypass

J. Bento, F. Caspers, A. Mostacci

http://indico.cern.ch/getFile.py/access?contribId=0&resId=1&materialId=slides&confId=59490

Measurements on the RF Bypass in SS89 in the PS

J. Bento, H. Damerau



The Max peak beam intensity will be considered with
2.5E13 ppb and 130 ns bunch length

$$I_{beam\ peak\ Linac\ 4\ at\ ej} = \lambda_{pp\ ej} = \frac{\pi}{2} \cdot \frac{Q_{Bunch}}{T_{Bunch}} = \frac{3.14 \cdot 2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{260 \cdot 10^{-9}} = 48 A_p$$

(The peak beam current in 2012 in the PS is 100 A_p)

$$I_{beam\ peak\ Linac\ 4\ at\ inj} = \lambda_{pp\ inj} = \frac{\pi}{2} \cdot \frac{Q_{Bunch}}{T_{Bunch}} = \frac{3.14 \cdot 2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{800 \cdot 10^{-9}} = 15.7 A_p$$

Appendix

$48\ A_p$ in a single $0.5\ \Omega$ resistor corresponds to $1152\ W_p$ and $24\ V_p$

In the nominal case, this current will be shared by the 3 bypasses

=> $16\ A_p$ (= 48/3) in each $0.5\ \Omega$ resistor corresponds to $128\ W_p$ and $8\ V_p$

For the resistance average power estimation it is reasonable to assume a centered beam => equally shared beam current

The average beam current is for an average T_{REV} = 1.425 MHz:

$$\overline{I_{Beam\ during\ acceleration}} = \frac{2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{\overline{T_{REV}}} = 5.7\bar{A}$$

For a 500 ms accelerating cycle within a 0.9 s cycle, the maximum average beam current will drop to:

$$\overline{I_{Beam\ max-Linac\ 4}} = 3.1\bar{A}$$

The average beam current at extraction with T_{REV} = 546 ns:

$$\overline{I_{Beam\ at\ extraction}} = \frac{2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{546 \cdot 10^{-9}} = 7.3\bar{A}$$

The average beam current at injection with T_{REV} = 1000 ns:

$$\overline{I_{Beam\ at\ injection}} = \frac{2.5 \cdot 10^{13} \cdot 1.6 \cdot 10^{-19}}{1000 \cdot 10^{-9}} = 4\bar{A}$$

Appendix

To compute the average power, we shall assume the beam centered and its image current equally shared within the 3 bypasses

$$\overline{I_{Bypass\ max-Linac\ 4}} = 1\bar{A}$$

This implies that the average power to be dissipated into each 0.5 Ω resistor is:

$$\overline{P_{Bypass\ max-Linac\ 4}} = 0.5\bar{W}$$

Recall:

The max peak beam current in a single 0.5 Ω resistor corresponds to 1152 W_p and 24 V_p

RMS current:

$$I_{RMS} = \sqrt{\frac{1}{T_{REV}} \cdot \left[\int_0^{T_{Bunch}} \left(I_{Peak} \cdot sin\left(\frac{2\pi}{2 \cdot T_{Bunch}} \cdot t\right) - I_{Average}\right)^2 dt + \int_{T_{Bunch}}^{T_{REV}} \left(-I_{Average}\right)^2 dt\right]}$$

$$I_{RMS} = \sqrt{\frac{1}{T_{REV}} \cdot \left[\int_0^{T_{Bunch}} \left[I_{Peak}^2 \cdot sin^2\left(\frac{\pi}{T_{Bunch}} \cdot t\right) - 2 \cdot I_{Peak} \cdot I_{Average} \cdot sin\left(\frac{\pi}{T_{Bunch}} \cdot t\right)\right] dt + {I_{Average}}^2 \cdot T_{Bunch} + {I_{Average}}^2 \cdot (T_{REV} - T_{Bunch})\right]}$$

$$I_{RMS} = \sqrt{\frac{1}{T_{REV}} \cdot \left[\int_0^{T_{Bunch}} \left[I_{Peak}^2 \cdot sin^2\left(\frac{\pi}{T_{Bunch}} \cdot t\right) - 2 \cdot I_{Peak} \cdot I_{Average} \cdot sin\left(\frac{\pi}{T_{Bunch}} \cdot t\right)\right] dt + {I_{Average}}^2 \cdot T_{REV}\right]}$$

$$I_{RMS} = \sqrt{{I_{Average}}^2 + \frac{I_{Peak}^2}{T_{REV}} \cdot \int_0^{T_{Bunch}} sin^2\left(\frac{\pi}{T_{Bunch}} \cdot t\right) dt - \frac{2 \cdot I_{Peak} \cdot I_{Average}}{T_{REV}} \cdot \int_0^{T_{Bunch}} sin\left(\frac{\pi}{T_{Bunch}} \cdot t\right) dt}$$

$$I_{RMS} = \sqrt{{I_{Average}}^2 + \frac{I_{Peak}^2}{T_{REV}} \cdot \int_0^{T_{Bunch}} sin^2\left(\frac{\pi}{T_{Bunch}} \cdot t\right) dt - \frac{2 \cdot I_{Peak} \cdot I_{Average}}{T_{REV}} \cdot \frac{-T_{Bunch}}{\pi} \cdot \left[cos\left(\frac{\pi}{T_{Bunch}} \cdot t\right)\right]_0^{T_{Bunch}}}$$

$$I_{RMS} = \sqrt{{I_{Average}}^2 + \frac{I_{Peak}^2}{2 \cdot T_{REV}} \cdot \int_0^{T_{Bunch}} 1 - cos\left(\frac{2\pi}{T_{Bunch}} \cdot t\right) dt - \frac{4 \cdot I_{Peak} \cdot I_{Average} \cdot T_{Bunch}}{\pi \cdot T_{REV}}}$$

$$I_{RMS} = \sqrt{{I_{Average}}^2 + \frac{I_{Peak}^2 \cdot T_{Bunch}}{2 \cdot T_{REV}} - \frac{4 \cdot I_{Peak} \cdot I_{Average} \cdot T_{Bunch}}{\pi \cdot T_{REV}} - \frac{T_{Bunch}}{2\pi} \cdot \left[sin\left(\frac{2\pi}{T_{Bunch}} \cdot t\right)\right]_0^{T_{Bunch}}}$$

RMS current:

$$I_{RMS} = \sqrt{I_{Average}{}^2 + \frac{I_{Peak}^2 \cdot T_{Bunch}}{2 \cdot T_{REV}} - \frac{4 \cdot I_{Peak} \cdot I_{Average} \cdot T_{Bunch}}{\pi \cdot T_{REV}}}$$

$$I_{RMS} = \sqrt{I_{Average}{}^2 + \frac{I_{Peak} \cdot T_{Bunch}}{T_{REV}} \cdot \left(\frac{I_{Peak}}{2} - \frac{4 \cdot I_{Average}}{\pi}\right)}$$

At extraction:

$$I_{RMS} = \sqrt{7.3^2 + \frac{48 \cdot 130\,ns}{2 \cdot 546\,ns} \cdot \left(\frac{48}{2} - \frac{4 \cdot 7.3}{\pi}\right)}$$

$$I_{RMS} = \sqrt{53.3 + 5.71 \cdot (24 - 9.3)}$$

$$I_{RMS} = \sqrt{137}$$

$$I_{RMS\,ej} = 11.7\,A$$

At injection:

$$I_{RMS} = \sqrt{4^2 + \frac{15.7 \cdot 400\,ns}{2 \cdot 1000\,ns} \cdot \left(\frac{15.7}{2} - \frac{4 \cdot 4}{\pi}\right)}$$

$$I_{RMS} = \sqrt{16 + 3.14 \cdot (7.85 - 5.09)}$$

$$I_{RMS} = \sqrt{24.7}$$

$$I_{RMS\,inj} = 5\,A$$

RMS current:

The average RMS current along the cycle is thus $8.35\ A$

For an average duty cycle of 450 ms beam time / 900 ms cycle length = ½ = 50% the average RMS value needs to be multiplied by 1/ sqrt(2) = 0.707

The RMS beam current to be taken into account should thus be 8.35 x 0.707 = 5.9 A

Into 0.5 Ohms this mean a RMS power of 3 W

We thus need a 3 W RMS 0.5 Ohm resistor or two 1.5 W / 1 Ohm resistors in parallel.

Appendix

http://www.vishay.com/docs/52023/chp.pdf

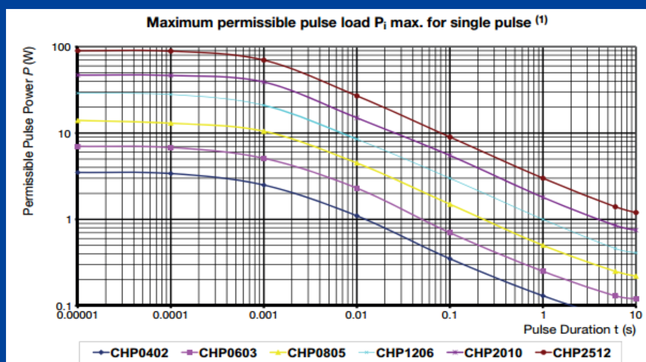
VISHAY.

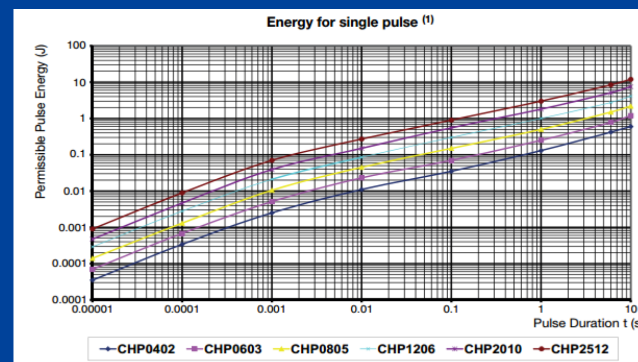
www.vishay.com

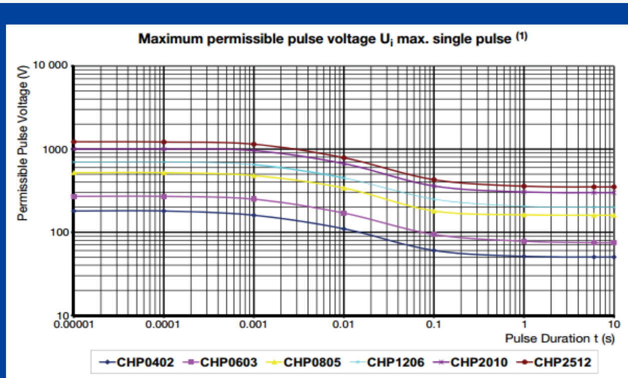
CHP, HCHP

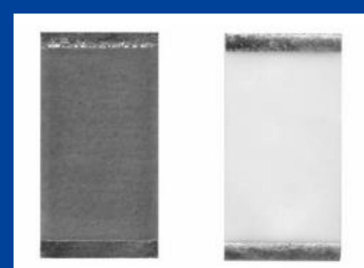
Vishay Sfernice

STANDARD ELECTRICAL SPECIFICATIONS								
MODEL	SIZE	RATED POWER Pn W	LIMITING ELEMENT VOLTAGE V	MAX. OVERLOAD VOLTAGE V	RESISTANCE RANGE [1] Ω	TOLERANCE ± %	TEMPERATURE COEFFICIENT ± ppm/°C	UNIT WEIGHT mg
CHP2512 CHP2512	2512	2.000 [3]	250	500	0.1 to 100M	0.5, 1, 2, 5	100, 200	42









PSB RF bypasses
References

http://indico.cern.ch/getFile.py/access?contribId=0&resId=1&materialId=slides&confId=59490

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