CIRCUIT DESIGN OF A SELECTIVE 2/3Ω PREAMPLIFIER.

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ABSTRACT:

The 2/3Ω Preamplifier, which is described here, is an electronic developed for the VIRGO experiment. This electronic is able to convert the currents coming from detection photodiodes into voltages.

Its aim is to measure selectively the modulated beams powers from the interferometer at 2Ω & 3Ω frequencies and to reject the signal at the Ω frequency.

The electronic board is implemented directly behind the photodiode and the filtering is passive, allowing a noise reduction and so a higher dynamic.

The two output signals are transmitted on a 50Ω line to the corresponding demodulation board.

CONTENTS: pg.

1- **Introduction: principle and general description of the *2/3Ω PREAMPLIFIER*.**

The 2/3Ω PREAMPLIFIER allows to convert into voltages the 2Ω & 3Ω currents coming from the photodiodes and to reject the Ω current.
The preamplifier does not transmit the DC current to the demodulation board because it is already transmitted by the Ω readout electronic.

This electronic is able to bias the photodiode (–5V).
The inputs and outputs connections are BNC standards.
A calibration input allows to perform preamplifier transfer functions.
The currents conversions are performed using two passive filters.

The preamplifier delivers two independent output channels (2Ω & 3Ω), buffered using AOP in a follower mode.

It has been designed to be compatible with the detection photodiodes and also with the existing demodulation boards electronics.

The dynamics and the DC components of the signals impose the use of a passive preamplifier.

Basically, the Ω frequency is about 6,25MHz, the 2Ω frequency about 12,5MHz and the 3Ω frequency about 18,75MHz.

The specification expected a 10E5 output dynamic.

2- ***2/3Ω PREAMPLIFIER*** **technical description and solutions (cf. schematics).**

The two signals amplifications are performed with 2nd order filters.

As the photodiode has a 300pF capacitance and an 8Ω serial resistance, its own transfer function is a 1st order low-pass filter.

So, a first stage performs a deadened 2nd order with this capacitance and resistance. With a good value of L3 we have an input impedance adaptation, which allows to have a constant input gain on the interesting frequency bandwidth.

In the same time, an adjustable inductance L4 with a serial capacitance C4 perform a notch at the frequency Ω, so the Ω component is eliminated.

Then the signal is splitted in three branches:

- The DC branch: the impedance seen in DC is very low thanks to an inductance (L1 & L2) connected to the ground. So the DC component is eliminated.

- The 2Ω branch: a 2nd order low-pass frequency filter resonates at the 2Ω frequency. This filter also performs a notch at the 2Ω frequency for the 3Ω branch. An adjustable inductance L5 with the C8 capacitance allows to trim accurately the resonance.

- The 3Ω branch: a 2nd order high-pass frequency filter resonates at the 3Ω frequency. This filter also performs a notch at the 3Ω frequency for the 2Ω branch. An adjustable inductance L6 with the C6 capacitance allows to trim accurately the resonance.

The maximum Ω rejection is obtained by the choice of the low-pass type for the 2Ω branch and the high-pass type for the 3Ω branch.

We used two opposed filters types (L-C / C-L) to limit the coupling between the two branches.

As the coupling is not totally eliminated, when the resonance is trimmed for a frequency in its corresponding branch, the notch frequency in the other branch is slightly shifted from the desired frequency. So we performed a second notch at the other side of the desired frequency to obtain a “notch zone”.

We placed C5 in parallel with the inductance L5 in the 2Ω branch.
We placed the serial capacitance C7 with the inductance L6 in the 3Ω branch.

The signals are adapted for two 50Ω lines using two CLC426 op amp in a follower configuration.

A switch before each CLC426 allows to disconnect the signal from the filter to the AOP: the result is to increase the rejections. It can be used for a single output signal application. S2 for 2Ω output and S1 for 3Ω output.

3- ***Tests & finalising.***

A third input allows to perform tests placing the S3 strap.

3-1 Tuning:

First, tune the Ω notch, then the two output frequencies resonances/notches.
The adjustable inductances range is +/- 10% of the central value.
So, they allow to tune the cut-off frequencies:

Ω → from 5,98MHz to 6,58MHz.

2Ω → from 11,8MHz to 13MHz.

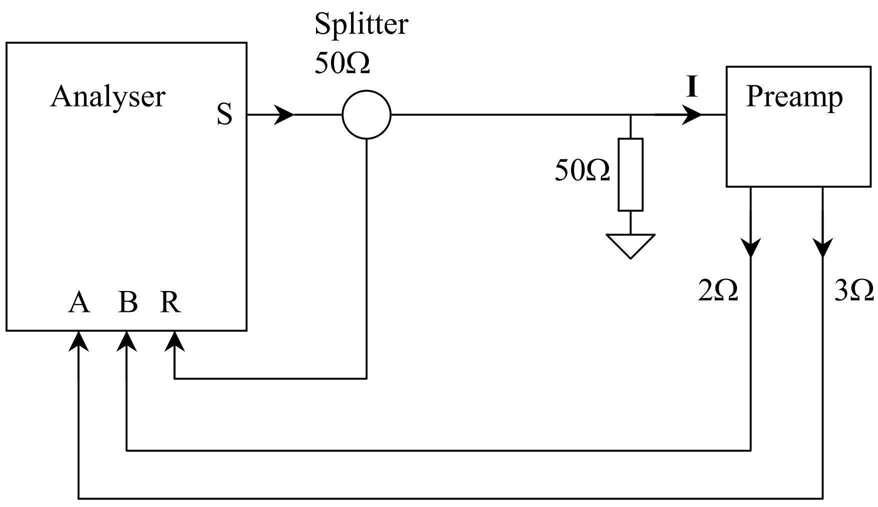
3Ω → from 17,4MHz to 19,4MHz.

3-2 Transfer functions:

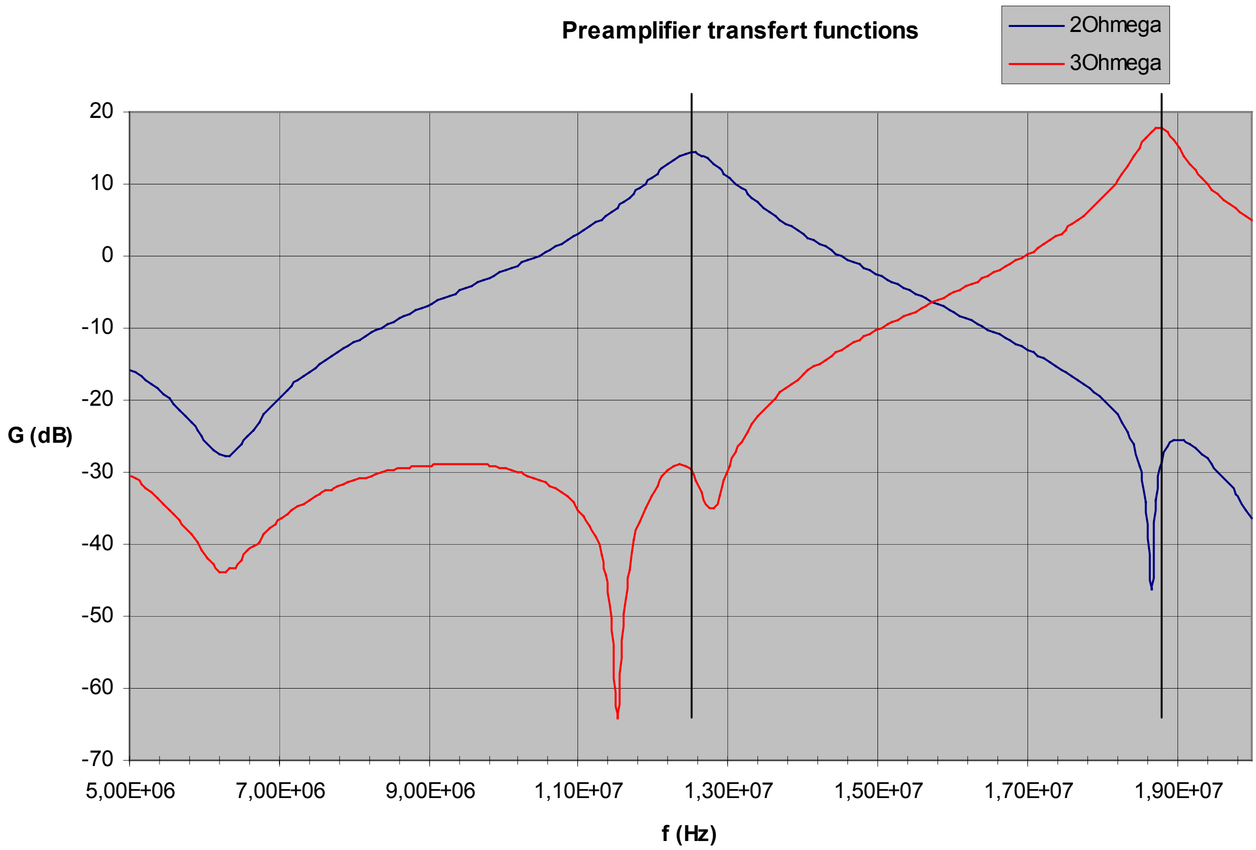
We performed the transfer functions using a frequency analyser:
S is the source; A, B, R the input channels.

The transfer functions are obtained dividing the channels A & B by R.
As the preamplifier input impedance is very low, a resistance can impose the input current I. So the equivalent transfer resistance can be written as follows:

$$G=\frac{A}{R} \text{ or } G=\frac{B}{R} \longrightarrow \boxed{\mathrm{Re}q=G.50\Omega}$$



So we obtain transfer functions referenced to 50Ω (test preamplifier):



3-3 Equivalent resistance results and rejections (test preamplifier):

- ***2Ω channel:*** for the Ω and 3Ω, we obtained a rejection about 44dB relatively to 2Ω, which represents a 6,3E-3 factor.

- ***3Ω channel:*** for the Ω, we obtained a rejection about 63dB relatively to 3Ω, which represents a 6,7E-4 factor.

  For the 2Ω, we obtained a rejection about 49dB relatively to 3Ω, which represents a 3,6E-3 factor.

In a single output signal application: for the 2Ω channel the 3Ω rejection is about 50dB and for the 3Ω channel the 2Ω rejection is about 73dB.

We produced 5 preamplifiers. The measured equivalent resistance are following:

	2Ω channel (50Ω normalized)					
n° préamplifier	Gnotch Ω (dB)	Réqui. (ohms)	Gpeak 2Ω (dB)	Réqui. (ohms)	Gnotch 3Ω (dB)	Réqui. (ohms)
1	-31	1,4	13,8	245	-37	0,7
2	-31	1,4	14,01	251	-34,5	0,95
3	-31	1,4	13,5	237	-35	0,9
4	-31	1,4	14	251	-33	1,1
5	-44	0,3	15,1	284	-34	0,4

	2Ω channel (50Ω normalized)					
n° préamplifier	Gnotch Ω (dB)	Réqui. (ohms)	Gnotch 2Ω (dB)	Réqui. (ohms)	Gpeak 3Ω (dB)	Réqui. (ohms)
1	-48	0,2	-32	1,25	14,81	275
2	-48	0,2	-33	1,12	14,6	269
3	-48	0,2	-32	1,25	15,1	285
4	-48	0,2	-33	1,1	14,5	265
5	-60	0,05	-30	1,6	14,8	275

The mean equivalent Ω resistance is about 1,4Ω for the 2Ω channel and 0,2Ω for the 3Ω channel.
The mean equivalent 2Ω resistance is about 253Ω for the 2Ω channel and 1,25Ω for the 3Ω channel.
The mean equivalent 3Ω resistance is about 0,8Ω for the 2Ω channel and 275Ω for the 3Ω channel.

The variations between the different preamplifiers depend on inductance quality factors.

3-4 Noise:

- ***2Ω channel:***

  The measured noise is about ***4,8nV/√Hz***.
  So the final output dynamic is about ***4,4E8√Hz***.

- ***3Ω channel:***

  The measured noise is about ***6,4nV/√Hz***.
  So the final output dynamic is about ***3,3E8√Hz***.

4- Conclusions.

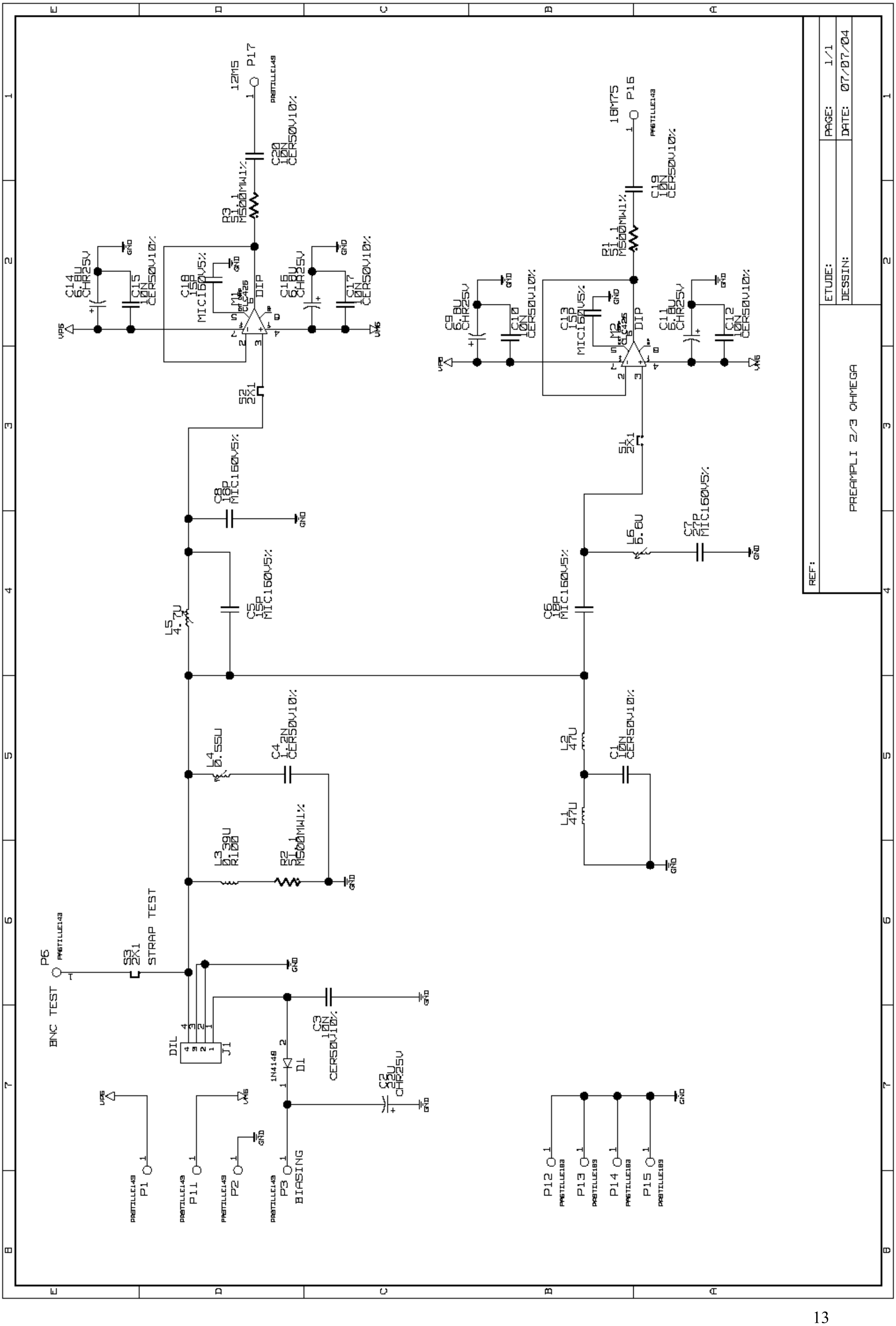
This 2/3Ω Preamplifier readout will allow to separate and convert photodiode currents into voltages with the expected output dynamics.

It will be used for classical VIRGO detection photodiodes and mechanics.

This electronic will be implemented on the B1, B2 and B5 VIRGO beams to involve the interferometer locking.

APPENDIX :

SCHEMATICS – BOARD IMPLANTATION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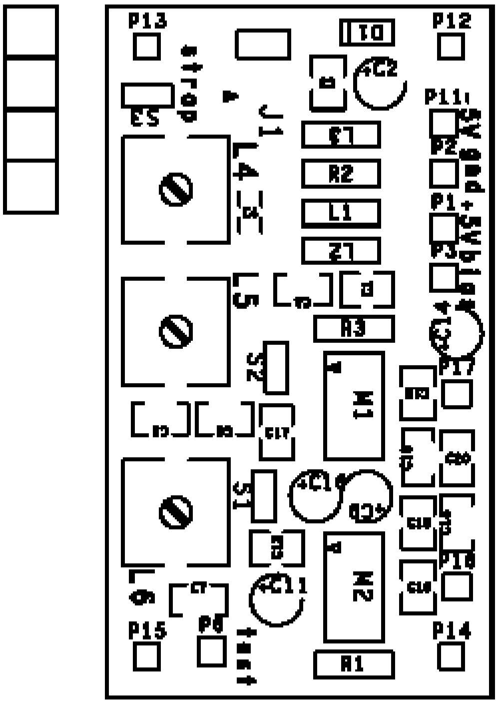
DATE: 07/07/04
ETUDE:
DESSIN:
REF:
12M5
P17
10M75
P16
R3 51.1 M500MW1%
C20 10N CER50V10%
R1 51.1 M500MW1%
C19 10N CER50V10%
C14 6.8U CHR25V
C15 10N CER50V10%
C18 15P MIC160V5%
M1 CLC426 DIP
C16 6.8U CHR25V
C17 10N CER50V10%
C9 6.8U CHR25V
C10 10N CER50V10%
C13 15P MIC160V5%
M2 CLC426 DIP
C11 6.8U CHR25V
C12 10N CER50V10%
S2 2X1
S1 2X1
C8 18P MIC160V5%
L6 6.8U
C7 27P MIC160V5%
L5 4.7U
C5 15P MIC160V5%
C6 18P MIC160V5%
L4 0.55U
C4 1.2N CER50V10%
L2 47U
C1 10N CER50V10%
L1 47U
L3 0.39U R100
R2 51.1 M500MW1%
P6
S3 2X1
STRAP TEST
BNC TEST
DIL
J1
C3 10N CER50V10%
D1 1N4148
C2 22U CHR25V
P1
P11
P2
P3
BIASING
P12
P13
P14
P15
GND
VP6
VM6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C2
strop
P11
5V
J1
L3
P2
gnd
L4
R2
L1
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L2
bias
P3
L5
R3
C14
S2
P17
M1
S1
C10
C9
P18
L6
C11
M2
C7
P15
P6
P14
test
R1