LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

-LIGO-

CALIFORNIA INSTITUTE OF TECHNOLOGY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DOCUMENT TYPE LIGO-E010052-00-C 3/20/01
INTENSITY SERVO DC PHOTODIODE PRELIMINARY ELECTRONICS DESIGN
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Distribution of this draft:

This is an internal working note
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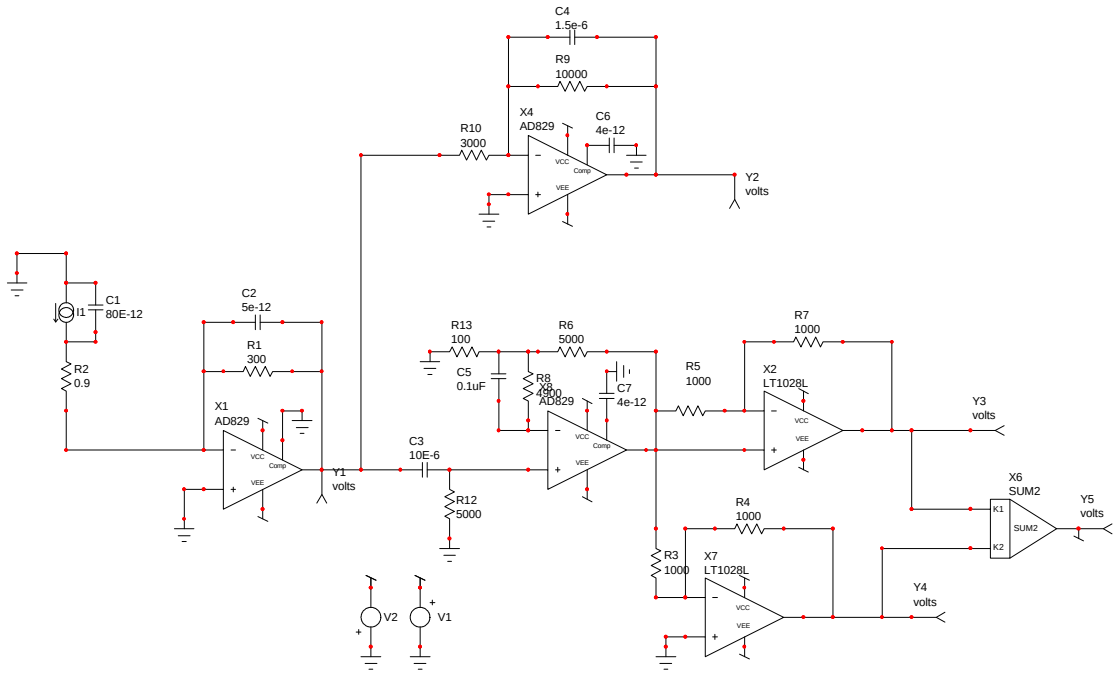
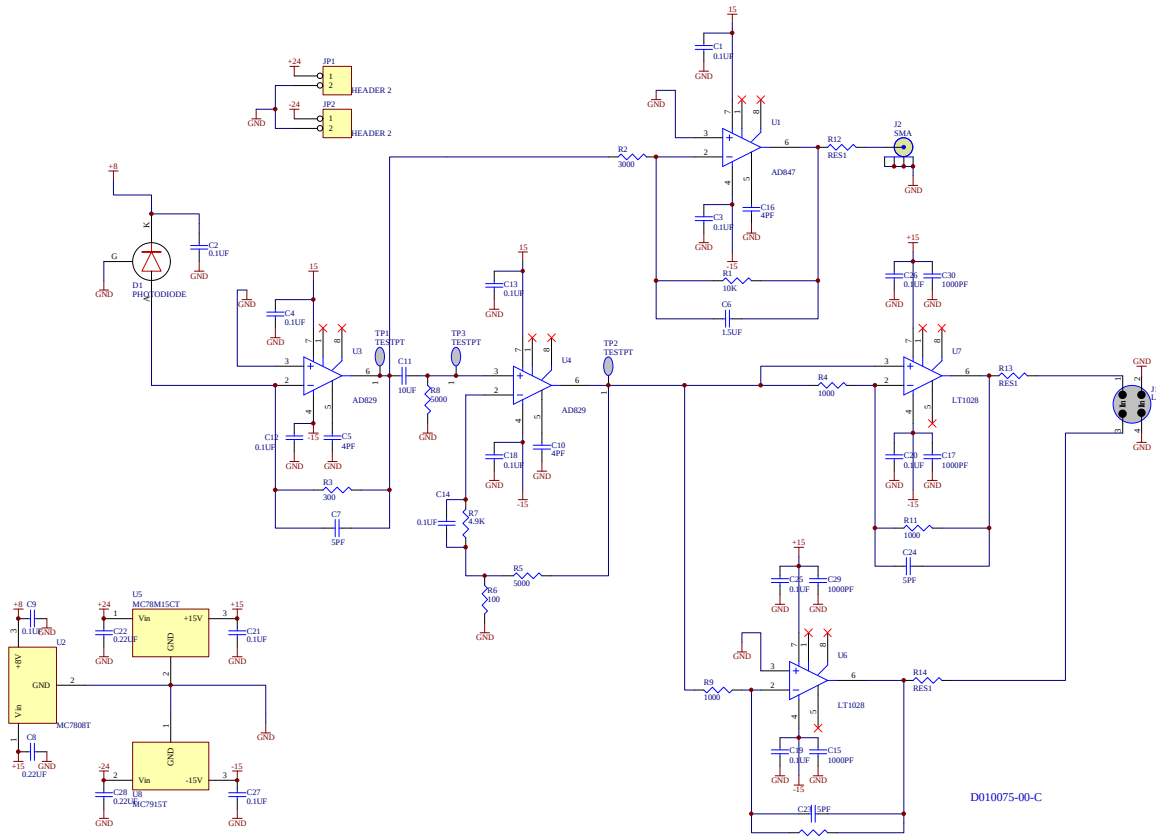
Following the specifications given to me by R. Karwoski [1], I have come up with the following DC photodiode design:



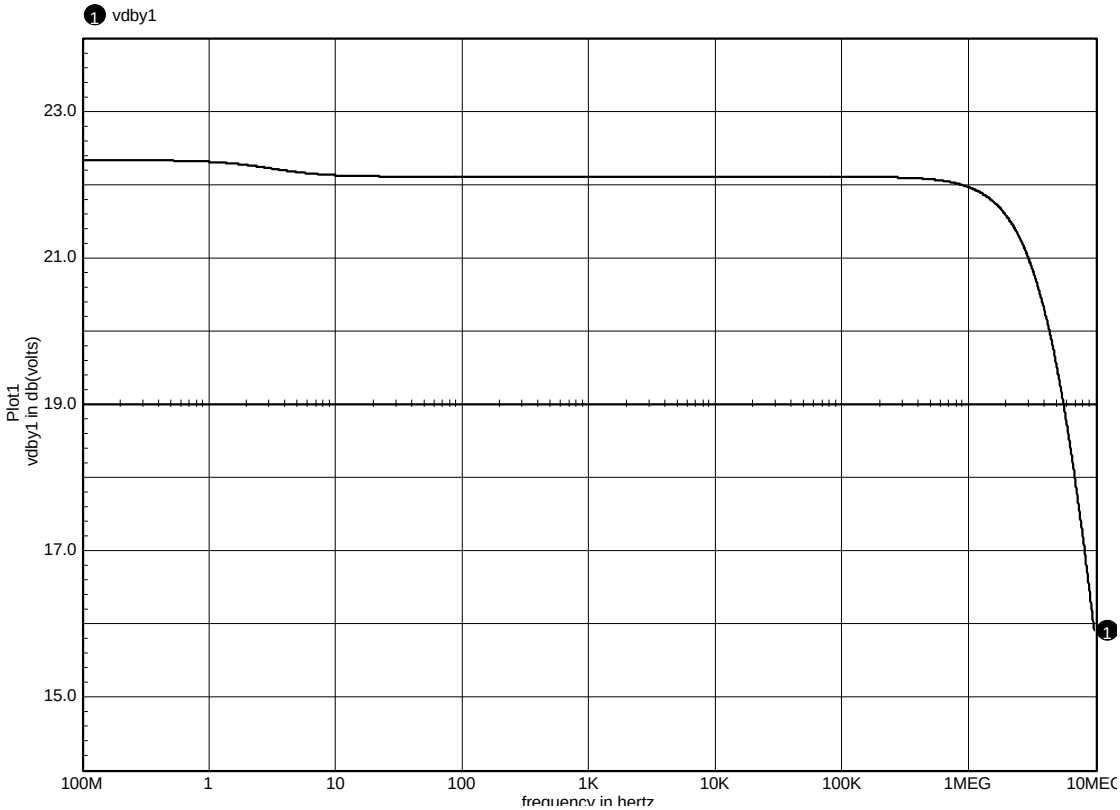
The performance of this design is shown on the following pages. All of the simulations have been performed in Intusoft SPICE.

The first stage has a transimpedance of 300 Ω. After this stage, the signal is split. One path goes to a DC output stage with a DC gain of 10, and a low pass filter corner frequency of 100Hz. The second path goes through a high pass filter with a corner frequency of 10 Hz. This path then goes through a non-inverting Op Amp configuration with a gain of 51. The result of this is then split off in two directions, and passed out as a differential signal [2b]. The phase at 100 KHz is less than 1° which fits well inside the 5° spec [2a].

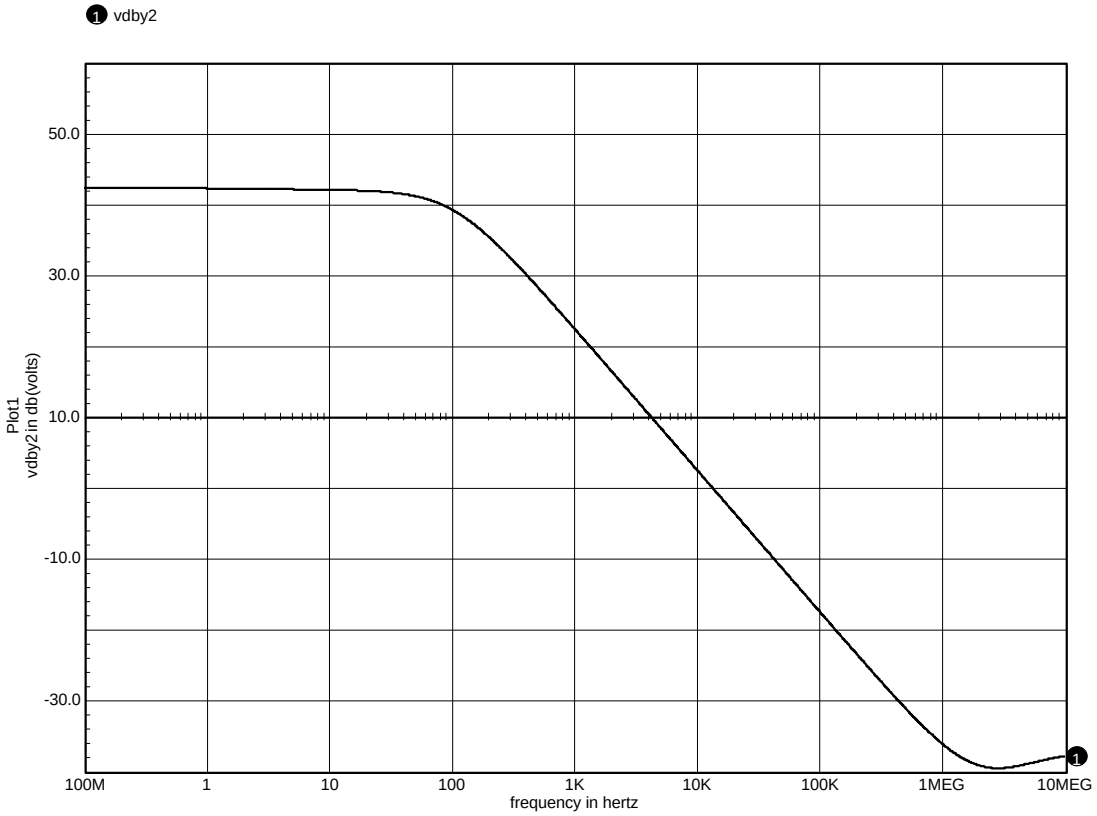
Here is the schematic as it exists in Protel as of 4/10/01:



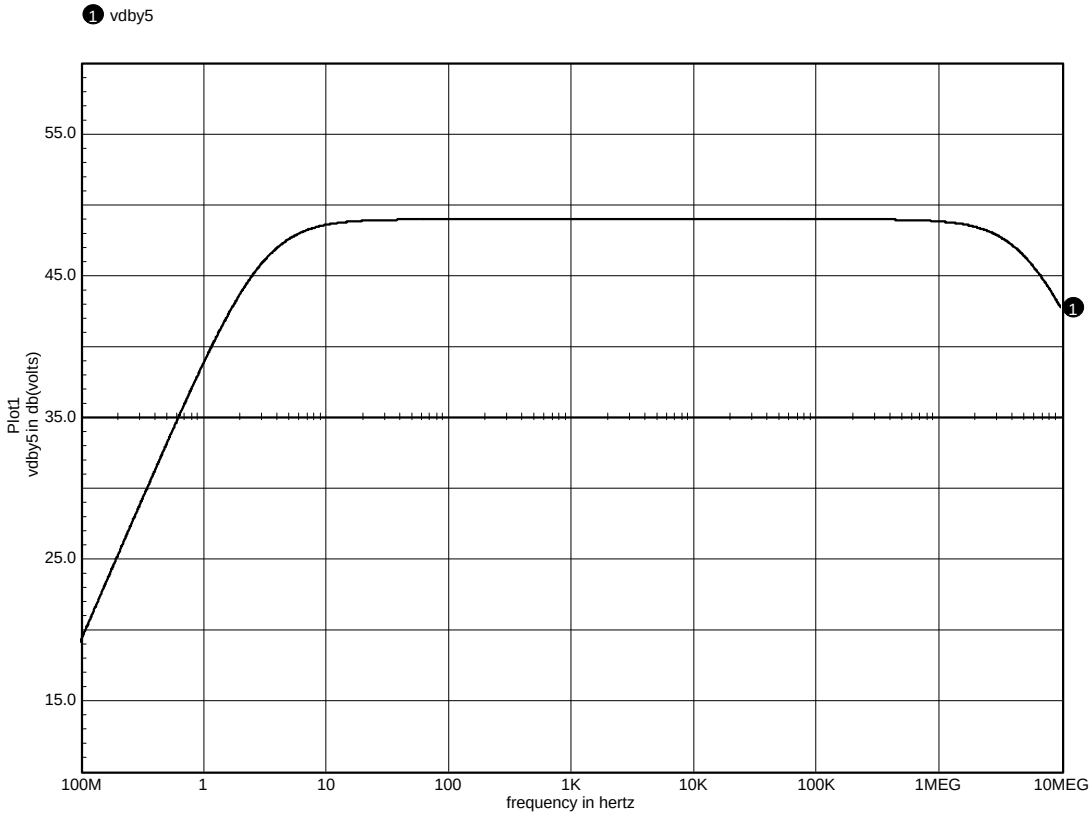
In this first plot, the output of the first stage is shown in dB versus frequency. It has a relatively flat gain of just over 22dB from the input current.



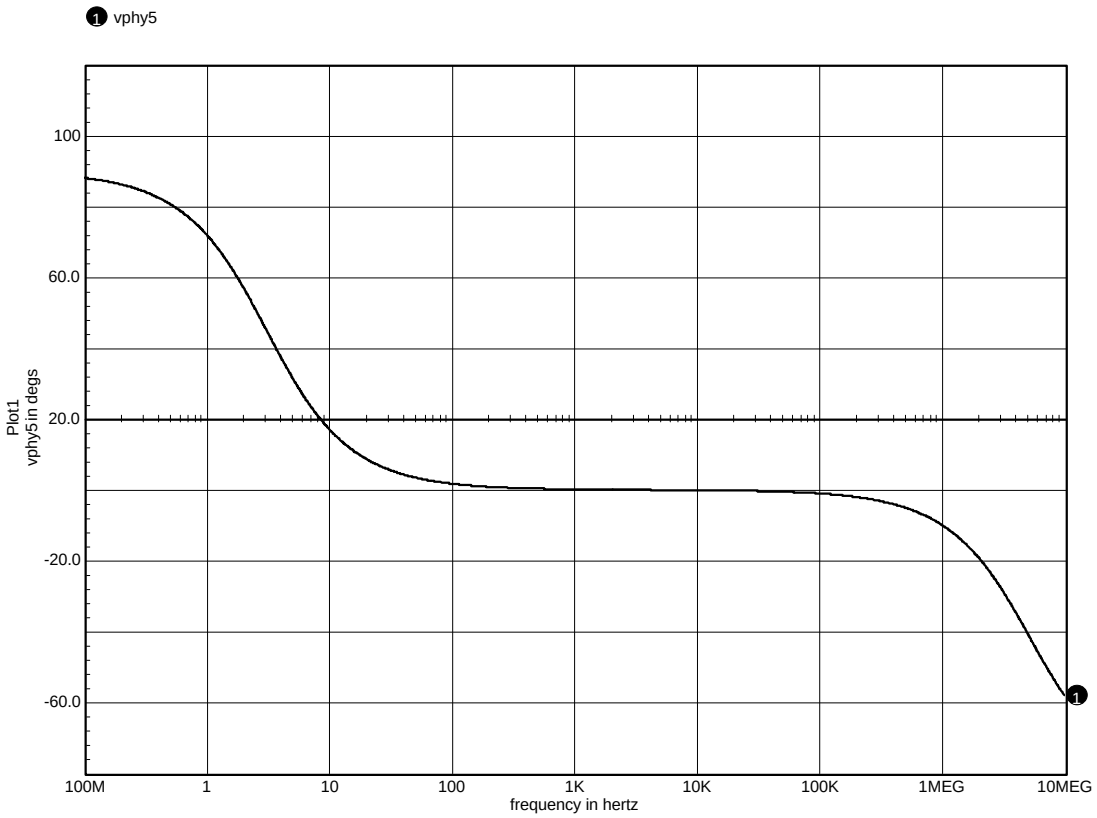
The next plot shows the DC output, with its corner frequency of 100 Hz.



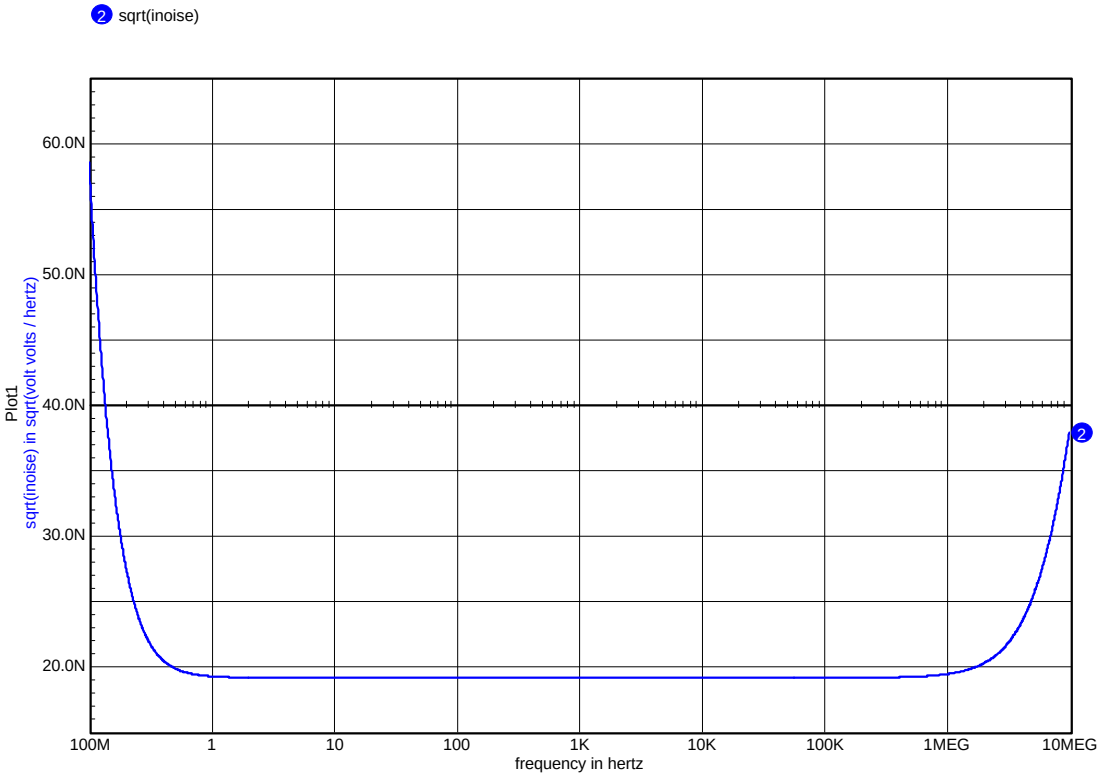
In the following plot, the differential output is shown that has an overall gain of two.



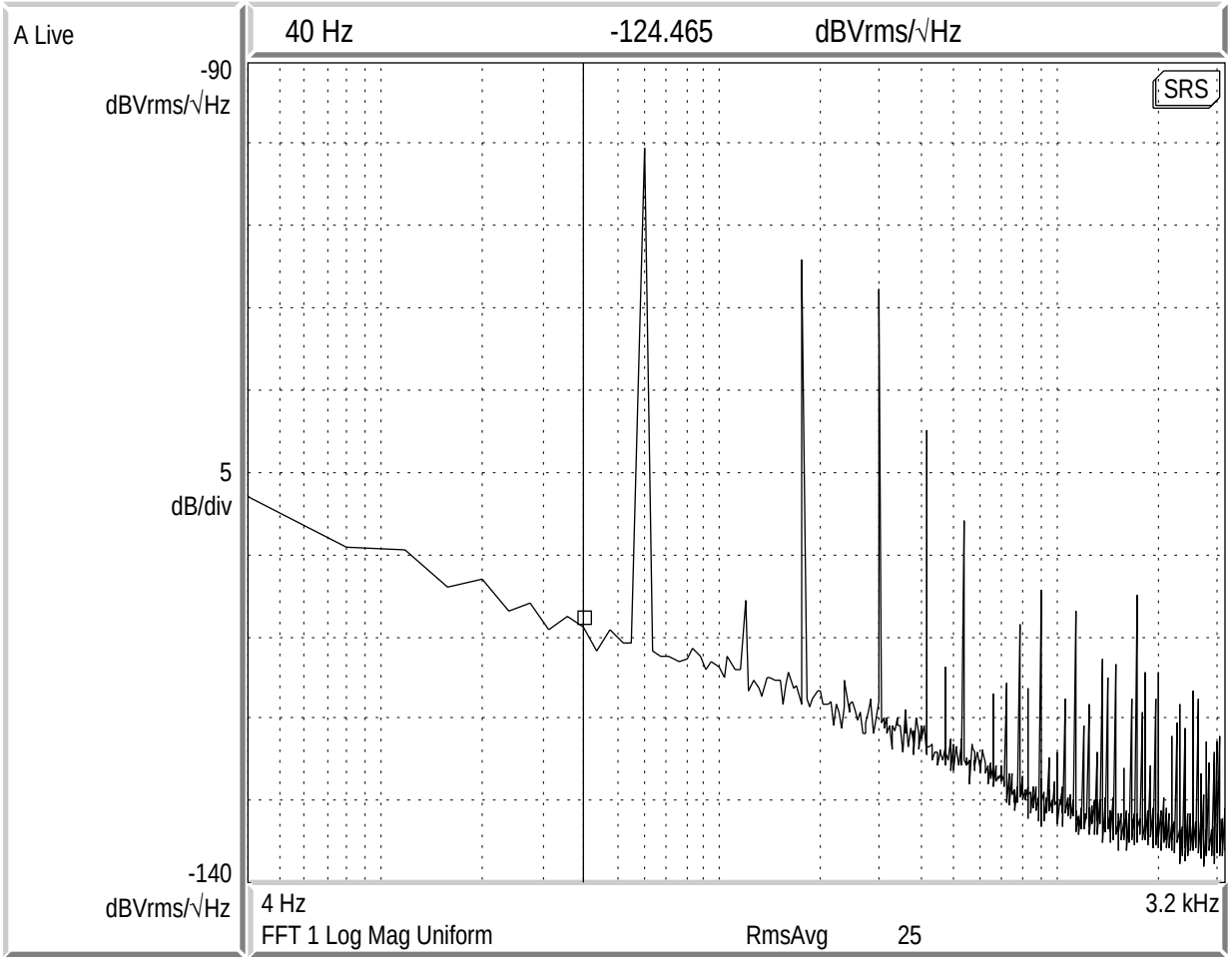
Next, the phase of the output is plotted versus frequency.



Finally, the next plot shows the input referred noise of the simulation. It seems from the graph to be around 19nV/√Hz input referred noise from 1 Hz to 1MHz.



The next page shows the actual noise curve taken 4/26/01. Because the gain of the circuit is 100, the circuit's input referred noise is 40dB better than the graph, or –164.46 dBV/√Hz @ 40Hz, and gets better after that.



4/26/01 09:46:59

1) Specifications email from R. Karwoski 2/27/01

X-Sender: karwoski@acrux.ligo.caltech.edu
X-Mailer: QUALCOMM Windows Eudora Pro Version 4.0
Date: Tue, 27 Feb 2001 15:50:29 -0800
To: babbott@ligo.caltech.edu
From: Rick Karwoski <karwoski@ligo.caltech.edu>
Subject: PD Gain info
Cc: rjk@ligo.caltech.edu

Ben,

Following up on our conversation yesterday, here is some data I think you will find useful:

At the Lauritsen Lab with the existing photodetector assembly:

1) 3 mw of laser lite
2) DC reading at the photodetector output: 3VDC

Now superimposing a fairly low frequency at the current shunt input:

3) 1.5 v p-p sinusoid
4) produces an A.C. level at the photodetector output: .012 v p-p.

Here are some of my initial thoughts:

I am not sure about the details of the photodetector circuit, but let's say for the sake of argument that it is a single trans-type circuit. 3 mw of laser lite producing 3 VDC indicates an Equivalent Resistance of 1000 ohms. I'm sure that is not the case but it serves as a reference.

Now looking at items 3 and 4. 1.5 v p-p at the current shunt produces .012 volts p-p @ the PD -- that's a gain of about .012/1.5 = .008 for the *shunt-PD* block.

Using unity gain as a convenient objective for the block, a secondary stage gain of 125 would be required. However, recalling your initial PD circuit with a feedback resistor of 300 ohms -- roughly 1/3 of the table-top unit Equivalent Resistance -- to achieve a unity gain would require an additional gain of 375 in the subsequent (i.e., your a.c.-coupled) stages.

By the way, with the laser running free, the secondary gain of 100 produces noise which extends about +/-100mv pk. -- a comfortable amount. This amount is what would be produced from your device should you create a *300-ohm-375* equivalent device. Your DC output would be on the order of 3 volt.

If you think a gain of 375 seems a bit high. I think you could relax it somewhat...Check this out. With 1 mw on the Laser, 1.5 v p-p ac excitation produces only 4 mv (not 12 mv) of ac output. One might assume that the small signal ac gain is related to the dc lite. Carrying the inference in the other direction, 10 mw of light is 3-1/3 greater than the 3 mw in the original scenario. Could we assume that the ac gain would increase by 3.3 if we used 10 mw as opposed to 3 mw. If that's the case you could cut your PD design down to a *300-ohm-125-Gain* thing and get the same results. I'd advise heading down to Lauritsen and getting some more data. Please let me know if you are interested in doing so. I would like to join you.

2) Verbally conveyed requirements from R Karwoski through personal communication.
    a) Design must have less than 5° phase noise back at 100 KHz.
    b) Design must transmit a signal out as a differential signal for optimal common mode rejection.