aLIGO DC Power Supply Voltage Noise Requirement

LIGO T1200070-v1
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1. Overview

Acceptance testing is underway for the aLIGO DC Power Supplies. There has historically been a difficulty in setting a reasonable requirement for the DC supply output voltage noise limits. The actual coupling mechanisms to interferometer noise are difficult to ascertain, but the noise coupling into garden variety LIGO electronics are better understood.

The following is a voltage noise coupling analysis of three commonly used aLIGO operational amplifiers (opamps). Using the derived coupling coefficient, a sensible maximum allowable power supply voltage noise vs. frequency can be conservatively stated.

2. **Assumptions -** In making the coupling factor determination, the following assumptions were made:
   - 2.1. For each opamp, the manufacturer's input voltage noise data is taken as the lowest achievable output voltage noise for any circuit topology. This is very conservative and tantamount to choosing a voltage follower configuration.
   - 2.2. In reality, local voltage regulators, and power supply filters aid in rejecting power supply noise at the circuit level. This added margin is not included, rendering the noise coupling analysis to be additionally conservative.
   - 2.3. The power supply rejection ratio vs. frequency is obtained from the manufacturer's data sheet.
   - 2.4. At frequencies above 10 kHz the typical opamp power supply rejection ratios decrease to a level that would be unrealistic to LIGO. The requirement at 10 kHz is simply extended as a constant number at higher frequencies. This isn't unrealistic given the actual board level DC power feeds are filtered and or regulated at the point of use in broad band applications.
   - 2.5. The calculated coupling coefficient and subsequent maximum allowable voltage noise is further reduced by a factor of 5 for additional safety margin.

3. **Data** - Table 1 through Table 3 shows spreadsheets to compare the noise coupling for various common LIGO opamps. The Power Supply Rejection Ratio (PSRR) numbers give the expected rejection of power supply noise as a function of frequency taken between the opamp power pin and the opamp output terminal. The equivalent power supply noise is obtained by dividing the opamp output noise by the power supply rejection ratio. The proposed requirement applies a factor of 5 safety margin to the equivalent power supply noise.

Table 1, OP27 Data

OP27				
Frequency (Hz)	**Opamp Output Noise (V/rtHz)**	**PSRR (dB)**	**Equivalent Power Supply Noise (V/rtHz)**	**Proposed Requirement, PS Noise/5 (V/rtHz)**
1E+01	3.00E-09	115	1.69E-03	***3.37E-04***
1E+02	3.00E-09	95	1.69E-04	***3.37E-05***
1E+03	3.00E-09	75	1.69E-05	***3.37E-06***
1E+04	3.00E-09	55	1.69E-06	***3.37E-07***
1E+05	3.00E-09	35	1.69E-07	***3.37E-07****

*See Section 2.4 Assumptions

Table 2, AD829 Data

AD829				
Frequency (Hz)	**Opamp Output Noise (V/rtHz)**	**PSRR (dB)**	**Equivalent PS Noise (V/rtHz)**	**Proposed Requirement, PS Noise/5 (V/rtHz)**
1E+01	4.00E-09	110	1.26E-03	***2.53E-04***
1E+02	1.70E-09	110	5.38E-04	***1.08E-04***
1E+03	1.70E-09	110	5.38E-04	***1.08E-04***
1E+04	1.70E-09	100	1.70E-04	***3.40E-05***
1E+05	1.70E-09	80	1.70E-05	***3.40E-05****

*See Section 2.4 Assumptions

Table 3, LT1125 Data

LT1125				
Frequency (Hz)	**Opamp Output Noise (V/rtHz)**	**PSRR (dB)**	**Equivalent PS Noise (V/rtHz)**	**Proposed Requirement, PS Noise/5 (V/rtHz)**
1E+01	3.00E-09	110	9.49E-04	***1.90E-04***
1E+02	2.70E-09	90	8.54E-05	***1.71E-05***
1E+03	2.70E-09	70	8.54E-06	***1.71E-06***
1E+04	2.70E-09	50	8.54E-07	***1.71E-07***
1E+05	2.70E-09	30	8.54E-08	***1.71E-07****

*See Section 2.4 Assumptions

4. **Requirement** – Figure 1 shows a curve that defines the maximum allowable noise level vs. frequency using the data from an OP27 and the assumptions outlined in the previous sections of this document. Given the well understood nature of the OP27 opamp, and the generously conservative assumptions used to derive this requirement, this curve should be used for acceptance testing of the aLIGO DC power supplies.

Figure 1