aLIGO DC Power Distribution Review: Charge and Reviewers' Comments

February – March 2011

1st email: Introduction and Charge to Reviewers

Dear Colleagues:

You are invited to participate in the final design review of the aLIGO DC Power Distribution Design. This is the system that will provide the DC low voltage power for aLIGO's electronics and computers. The distribution system is to be from banks of linear DC power supplies located outside of the sensitive electronics areas and conducted through cable pairs to electronics racks located on the interferometer floor and to electronics rooms that house the data converting, signal processing, and computing equipment. DC power and only DC power will be supplied to such gear in order to minimize 60 Hz AC induced noise. This design describes that system.

You have been selected to help with this review because of your familiarity and expert knowledge of a particular aLIGO subsystem. I have tried to match each major subsystem with a technical person closely associated with that subsystem. I have included people with primary safety and QA responsibilities as well. Also on the email list are a number of people that have been cc'd because of their expert knowledge of related systems. Their comments are welcome, although I will not twist their arms to participate in the writing of the final recommendation.

The review will be carried out through emails, web pages, and teleconferences. A final recommendation will be sent to aLIGO management.

This review is intended to determine if the proposed design is feasible, documented, and ready to begin procurement and fabrication. Please read the design document, T1100046-v1 (see links below) and prepare comments as to this design's:

* readiness for fabrication
* adequacy of documentation
* does it meet technical requirements for loads, voltages, noise, monitoring, control
* is it maintainable
* are its anticipated costs reasonable
* does it meet safety standards
* does it have suitable QA checks and measures

Please send your comments to me by COB Wednesday, Feb. 23, 2011. I will collect and organize your comments and questions. These will be forwarded to David Kinzel's team for their consideration. We will have a teleconference on Wednesday, March 2, 2011, to discuss the comments and replies. I will then ask for final comments and draft a final report.

The lead engineer is David Kinzel. He has prepared documentation defining the design and collected links to related documents. These are available in the DCC as:

T1100046-v1, "aLIGO DC Power System Design"
https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=32297

Related Documents:

* LIGO-D1003141: Rack and Cable Tray Layout, LVEA, L1
* LIGO-D1002704: Rack and Cable Tray Layout, LVEA, H1 H2
* LIGO-G1000552: aLIGO DC Power Distribution Racks etal
* LIGO-G1001030: Rack Names
* LIGO-G1001031: CDS Electronics Room (CER) Layout
* LIGO-G1001032: LLO CDS Room and Rack Layout
* LIGO-T1100047: aLIGO DC Power Supply Requirements
* LIGO-T1100048: aLIGO Wiring Conventions (and Their History)
* LIGO-T1100049: IO Extender Power Measurements
* LIGO-D070124: Rack Input Power Box
* LIGO-D1002189: DC Power Strip - Standard Voltages
* LIGO-D1002209: DC Power Extension Cord
* LIGO-D1002475: DC Power Pigtail Cord
* LIGO-D1100034: DC Power Strip - Custom Voltage

Thank you for your help in carrying out this review in a timely manner.

COMMENTS

Rai Weiss

Notes on DC power strategy and components

Most of this looks OK and shows some hard work.

Here are my comments on the documents.

T1100047 Requirements for the power supplies

Missing is a critical requirement that when power fails the voltage of the supplies does not go above the regulating voltage.

Missing is a critical requirement that after a power failure and a sudden turn on of the power the voltage does not go above the regulating value.

Missing is the need or desire or requirement that the voltage at the relay rack be controlled to allow for cable losses. A statement in LIGO G1000552-V5 p16 about remote sensing being useless when cables are too long is not true. That is exactly when remote sensing is most needed. One has to shield the return sense connections to avoid oscillation and noise. I assume that that each chassis has its own regulator, but even so one needs to design the regulator power dissipation and dynamic range based on a specification for the variation in the input voltage. I did not find a value for the wire gauge to allow 20A to flow. One needs a condition for how much voltage drop one is willing to accept.

Comment [dlk1]: Added to T1100047-v2

Comment [dlk2]: Added to T1100047-v2

Comment [dlk3]: This is the motivation for variable supplies – so that the voltage can be adjusted at the receiving rack. It did not seem that the requirements document was the place for this explanation. Sorry.

Comment [dlk4]: Perhaps I anticipated too far in advance. The manual for the supplies that I investigated says "Up to 0.5 volt per load wire can be compensated using remote sensing." Our line length loss for 12AWG copper is both theoretically and experimentally greater than 0.5 volts.

Comment [dlk5]: Each power strip is rated to handle 20A and provides 24 connections, with the intent that geometrically, those connections can service one rack's worth of chassis. Each power supply is rated to provide 20A, and a set of 2 power supplies provide the plus and minus voltages specified. Extension cables are estimated at 100 ft, average, and 12AWG stranded wire was selected. It may need to be larger to accommodate actual loads. A chassis is estimated to draw 1A, average, and one set of two power supplies services one power strip. Each extension cord (from power strip to chassis) is 3 ft long, made from 16AWG stranded copper, intended to handle 10A.

What conditions are being imposed to avoid oscillations in one chassis to propagate to other chassis through the finite impedence of the various busbars and cables from the supplies to the racks. In other words what is being done to make the power system have a low impedence for high audio and RF frequencies. Are there filter capacitance and RF chokes provided in the power system at the rack level or does this become a requirement for each chassis separately?

What is the size and material of the bus bars in D070124. What is the strategy for these bus bars and other copper strips. How much inductance/length, capacitance to ground/length, resistance /length is allowed.

Power strips in D1002189 use connectors for the cables: are they strain relieved and clamped.

D1100034 and D1003141 are not associated with files.

The word chasses is new to me.

R. McCarthy

(I due know Daniel will not have time to review this but is quite concerned about the lack of power for Timing and ISC etc.) [see D. SIgg's comments below]

R. McCarthy First Comments:

LIGO-T1100047-v1 Section 3

One requirement is a Range of 0-25 Vdc . Why is this range required you have fixed output requirements +- some percent might make more sense. It would seem this might drive up the costs.

With Post regulation do the Ripple and drift requirements need to be so stringent?

Standard half-rack form factor or smaller should be an option.

Under mechanical should call out either cord connection terminal strip with barriers for the 120V input.

Where all subsystems informed of the Voltage change? At one time the DC requirements were for 6.5Vdc 12Vdc 18Vdc and 24Vdc. I know the timing system that will be in this room will require 12V.

LIGO-G1000552-V5

Comment [dlk6]: No provision has been made in the power distribution system, thus far.

Comment [dlk7]: I have uploaded an assembly document for D070124. The bus bars are insulated ground bars used in AC power distribution, and I cannot find direct specifications for them. They are used inside AC power systems that are themselves rated at 125A, so I infer that they will carry that much AC. They are built to handle wires from #4 AWG through #14 AWG. There are pictures in the assembly document.

Comment [dlk8]: There are jack sockets on the power strip connectors and screws on the extension cords. The cords are to be tie-wrapped to the racks.

Comment [dlk9]: D1100034 is now uploaded.

Comment [dlk10]: You found me out. I am a Francophile. No, actually, I thought the plural of chassis was chasses and that everyone else was misspelling the word. Ah, I am covered in rue. (Roux?)

Comment [dlk11]: As in comment 3 above, the purpose in variable power supplies is to accommodate the line losses of the extension cables.

Comment [dlk12]: Probably not.

Comment [dlk13]: Added to T1100047-v2.

Comment [dlk14]: Added to T1100047-v2.

Comment [dlk15]: Well, we did have at least two reviews at CDS Wednesday meetings. Other voltages are required as well – 9V and 36V come to mind. But these will be handled on an exception basis. This design is for the two ubiquitous voltages that could be handled by making standard components.

You specify 12 20Amp AC circuits per rack. This assumes every power supply is fully loaded at all times. Are the loads known that require this or is this conservative?

I am concerned that by not including the other Voltages that are required like PEM equipment or ISC RF or HV for SUS we are not providing an adequate view of the overall costs and space requirements.

Do you provide for any circuit protection? 20 Amp at 24V can make for an interesting spark and without remote monitoring may be difficult to diagnose.

LIGO-G1001032-V3

You show the End stations with the DC Supplies in the DAQ racks. Is there enough room to add the other voltages that will be required by other systems. Do you have a layout

Page 16 of G1001032 shows using 2/ 200 A/480VAC feed s for 192Kw of power. Why not 3ph transformer?

I could not find anything on costs for this system.

Is there a mature understanding of the End Station Loads? In particular ISC.

Comment [dlk16]: This is conservative, but the educated guesses have been refined along the way. For instance, the buffers on the circuit boards doubled the current requirements. Original estimates were for 10A supplies.

Comment [dlk17]: Good concern. I share that concern, and have satisfied myself that it will be addressed as needs are exposed with clarity.

Comment [dlk18]: Suggestions?

Comment [dlk19]: G1001032 is an active work-in-progress to which I add information as it arrives. The End Stations are becoming clearer, but are still not fully designed. Other voltages will be added as they are discovered.

Comment [dlk20]: It is actually 480V 3P.

Comment [dlk21]: The procurement review will follow this technical review, though the assessment you provide later is close. It's more like 750K.

Comment [dlk22]: Understanding is ripening as we speak.

Richard McCarthy Comment 2: Power Supply Follow Up - Cost and Wattage Table

Per G1000552 4 full racks in Corner station
A positive and negative supplie per row

Rack	#Power Supplies	Watts/Supply	Watts +50% efficiency
L1-VDC-C1	24	480	23040
L1-VDC-C2	24	480	23040
L1-VDC-C3	24	480	23040
L1-VDC-C4	24	480	23040
Total Corner Station	96		92160 Watts
3 IFO's	288		
GSA JQE 24-20		$2,109	
Corner Station/IFO	$202,464		
Total Corner Station	$607,392		

Each supply is 480 Watts output 50% efficiency so 960 Watts Total.

J. Heefner

1. In document G1000552-v5, page 16 it is stated

"All DC Power Supply returns will be tied together (bonded) at the DC Power Rack to avoid ground loops"

Does this mean that ALL DC power returns going to all racks are tied together . I am not sure we want to do this. It may be better to float them at the DC power end and allow each subsystem to deal with the grounding. I don't think we want to tie everyone together.

2. Have you done any voltage drop calculations on the cable runs for the expected loads?

3. Has the SOW been written for the procurement of the power supplies?

4. Are there complete fab drawings and fabrication plans for the DC boxes for each rack? What is the procurement plan for these boxes?

5. What is the schedule for procurement, fabrication and installation? Does it support the aLIGO install schedule?

6. What is the plan for all of the other voltages that are needed for cameras, etc.

7. What is the plan for the power cable runs to the field racks. Do we have an idea of the needs? Do we have an idea of the loads? What gauge?

Comment [dlk23]: This issue does need discussed. The eLIGO power supplies were all tied together in their racks and the racks were all bonded to the ground grid buried in the back yard.

Comment [dlk24]: Yes. There will be some runs that will require heavier gauge wire due to load and distance. For this reason, there may be a temptation on some racks to increase the number of power strips instead of the gauge of the wire. This would require more power supplies which would be more expensive than thicker wire.

Comment [dlk25]: T1100047 is the SOW.

Comment [dlk26]: If you are asking about the power strips, yes, there are drawings. BOMs have been developed and a first-run build is imminent.

Comment [dlk27]: Technical review, then procurement review, then lead time, then delay… all things in their order is the order of the day…

Comment [dlk28]: To be developed. I have broad outlines into which I solicit things to put.

Comment [dlk29]: As information is provided, the needs are being addressed. Input helps.

R. Abbott

Review comments in no specific order.

1. The supplied link to D1003141 points to a document that has not yet been uploaded.

2. In G1000552, and perhaps other's, there's reference to tying all the grounds together at the DC power supply racks. It might be a good idea to discuss this some and see if we think that's a good idea when considered in context with the remote loads.

3. It may be too late, but I always thought the DC power supply racks ought to be connected to the remote racks by conduit. There are statements that say there's no need for shielding, which may be true, but difficult to retrofit if we find out they are needed.

Comment [dlk30]: Yes.

Comment [dlk31]: This issue does need discussed. The eLIGO power supplies were all tied together in their racks and the racks were all bonded to the ground grid buried in the back yard.

Comment [dlk32]: Conduit may be a good idea for another reason: large gauge wire.

4. Will the DC feeds pass through the laser diode room? If so, is there a likelihood of picking up radiated noise from the diode supplies?

5. In T1100047-V1, aLIGO DC power supply requirements, I don't see reference to a desire for voltage readback monitors of current and supply voltage. How is this being handled?

6. I don't see the details of how the power feeds to and from each rack are accomplished. There must be some sort of rack penetration or something. How is this done?

7. Are there numbers for the anticipated amperage requirements for each rack? It would be good to know where we sit in relation to the 20A power supply rating.

8. What do we plan to do with the front panel current limit adjustment? Should it just be set to 20A, or somehow set relative to a rack's current draw? This is where we will want to know what the supply current and voltages are, as we don't want to have to be suspicious that a supply has gone into current limit (perhaps due to the addition of another piece of hardware at 3am).

9. Is there cost data? I didn't stumble across it in my readings.

10. I know it's explicitly not in scope for this review, but can we afford the additional work and hardware associated with the "special" voltages needed by the timing system, RF distribution system, etc? I feel it's not such a bad time to talk once more about this, as we now know more about the number of outliers.

11. I am assuming the topic of power supply output voltage noise is adequately addressed in the ripple and drift specs listed in the requirements. Is this true?

12. What's the anticipated voltage drop from the supply room to a remotely located rack (assume a nominal current and worst case distance)?

Comment [dlk33]: No, the DC goes over the ceiling of the LDR.

Comment [dlk34]: This requirement is

Comment [dlk35]: The racks have access holes in the top cover. Signal cables and power cables will be isolated from each other.

Comment [dlk36]: Numbers are being added as they are available. See G1001032 slide 5. Of course, not all numbers are known, so a best guess has been used. That number is 20A of +-18VDC and 20A of +-24VDC for each rack.

Comment [dlk37]: Procurement is to follow. I have done quite a bit for this already, but it is not in final form.

Comment [dlk38]: Additional standards and guidelines can be added as we progress. This work lays the foundation for the most common requirements and hopefully, add-ons can fit into the schemes outlined.

Comment [dlk39]: Unknown.

Comment [dlk40]: An example distance of 200ft with 24V at 20A using #4AWG copper would lose 8.6% or 2V. The 25V supply with a 1V overshoot would therefore source 24V. This would reach from the furthest DC Power Rack to the PSL racks. Wire gauge is the solution to the line loss.

K. Thorne

Comments on the DC Power Design (T1100046)

1) Readiness for fabrication

Looks quite good. Documentation and prototypes for the DC power strips are on hand, and a head count of DC power supplies is available.

2) Adequacy of documentation

The documentation is quite good. It is hoped that the Powerpoint docs detailing what is in each rack can be extend to the DAQ equipment and can be maintained over time (and available to commissioners)

3) Does it meet technical requirements for loads, voltages, noise, monitoring, control?
The loads and voltages have been addressed. The uncovered needs for DAQ are that in the Common Electronics Room at LLO, we also need to provide 12V DC for the Timing Fanout, as well as unknown voltages for the network switches (CDS, GC, Camera).
I believe measurements of the voltage drop expected between DC Power Room and Common Electronic Room have been made recently, but could not find info on that here.
We still need to see how well the separation of DC power from ADC/DAC electronics will reduce electronic noise on the signals. Early monitoring of how this evolves over time will be needed.

Comment [dlk41]: Measured loss agrees with calculations from various worksheets.

4) is it maintainable?
There does appear to be sufficient room in front and behind each rack to access and replace equipment. Care will have to be taken in the wiring and cabling to ease access to components. The use of DC Extension cords to power each component will make it easier to change them out.

5) Are its anticipated costs reasonable?
I was not able to find the cost documents by following the documents included here. Where are they? I know that quotes have been obtained on the power supplies and the power strip and cord fabrication.

6) Does it meet safety standards?
I am not familiar enough with the safety standards to comment.

7) Does it have suitable QA checks and measures?
I did not find documentation specifically addressing the QA checks and measures. We may want some basic test plans and procedures to validate each components as it arrives from the vendor.

We should move forward with this

Minor points:
Correct spelling of 'chasses' to 'chassis'. [ouch]
On page 3 of T1100046, second paragraph, change "no requirement for -25V" to "no requirement for -24V DC".

Comment [dlk42]: OK. But 'irregardless' is still not a word.

Comment [dlk43]: So noted in T1100046-v2.

Z. Marka

Review of the proposed DC supply plans from the viewpoint of the timing system needs.

The timing system DC inputs are the following:
Masters: +12V, +24V
Fanouts: +12V
Comparators:+12V
IRIG-B: +12V

GPS Module: +24V
Slaves: +12V

Our major concern about the current DC supply plan is the* lack of 12V DC.
*I have discussed this issue with Daniel Sigg and he pointed out, that the RF sources also need 12V DC.

Comment [dlk44]: As a "non-standard voltage" 12VDC appears in just a few places and the MSR houses most of them. Thus the 12V could come from supplies housed in the FE racks. In other places, an 18VDC power strip outlet could be regulated.

The slaves are integrated and they will get 12VDC from the PCI-E chassis. However, I do not see any indication for providing 12V DC to the above mentioned timing system components.

B. Abbott

1) The presentation page referenced links that were missing documents: D1003141-x0 and D1100034-x0. These should either be removed, or their documents should be uploaded into the DocDb.

Comment [dlk45]: D1100034 is now uploaded.

2) What make and model power supplies will be used?

Comment [dlk46]: I have asked for bids. I received 2 no-bids. The supplies that qualify are KEPCO JQE25-20M.

3) If a 24V power strip can handle only up to four IO chassis, or 1 Coil Driver, why are there 24 plugs on each one? It seems like there should only be four plugs per strip at most.

Comment [dlk47]: I agree that a smaller one is needed – so that is what D1100034 is. Except it has 6 sockets.

4) I think the counts per rack are a bit off for seismic. If each channel of a coil driver is capable of driving a maximum of 4 Amps (+/- 20V over 5 Ohms) then each Coil Driver chassis would need its own 20A supply. It could use one plug of a 4-plug plug strip, and eliminate the need for a "High Current" distribution center. These distribution centers would only be able to supply one Coil Driver anyway, not much to distribute. The following pages have drawings of each rack, but the counts would be:

Comment [dlk48]: Thanks.

Rack	+18V	-18V	+24V	-24V	
C1 (HAMs 1&6)	1 (14 chassis)	1 (14 chassis)	3		2
C2 (HAMs 2&3)	1 (19 chassis)	1 (19 chassis)	5		4
C3 (HAMs 4&5)	1 (21 chassis)	1 (21 chassis)	5		4
C4 (BSC1)	1 (18 chassis)	1 (18 chassis)	4	3	
C5 (BSC2)	1 (18 chassis)	1 (18 chassis)	4	3	
C6 (BSC3)	1 (18 chassis)	1 (18 chassis)	4	3	
BSC4	1 (18 chassis)	1 (18 chassis)	4	3	
BSC5	1 (18 chassis)	1 (18 chassis)	4	3	

[please see attached pdf with his rack illustrations]

D. Sigg

1) ISC RF sources and all timing systems need 12VDC.

2) The slow controls uses 24VDC and it should be separated from the analog one. Are we using the same supply as the IO chassis?

3) All my ISC electronics requires sequencing of the supplies, i.e, the 24V must be higher than the 18V at all times (use relays or wire a 6V supply in series of the 18V).

4) I don't see a list of estimated current consumptions. How much headroom is there?

5) What is the thermal load? Is the cooling adequate?

6) What are the model number of the power supplies that are proposed? What alternatives have been looked at?

7) Other voltages than 18V and 24V are not mentioned, but we should make a list of the other voltages we already know. At this point it is not clear to me if this will add 10% or 100% scope.

J. Worden

Thermal load for the new H2 building – estimate based on ~40 (?) racks at 1kW of heat per rack. [Assume 50% efficiency for the linear supplies]

If this changes too much the HVAC for the new building will have to be upgraded.

Comment [dlk49]: OK, we'll work on 12V next. Is that both polarities?

Comment [dlk50]: We have agreed that IO chassis are on their own supplies.

Comment [dlk51]: So I heard. How will you handle this?

Comment [dlk52]: I have a partial list. But in any case, if more power is needed, we will run more power.

Comment [dlk53]:

Comment [dlk54]: Bids were solicited from Digi-Key, Allied Electronics, Kepco, and a fourth company. Digi-key, and Allied no-bid. Kepco bid. The fourth company did not bother to answer.

Comment [dlk55]: Probably closer to 10 than 100.

Comment [dlk56]:

1) We are attempting to remove all AC from the proximity of the IFO. PSL requirements force AC onto the LVEA floor. Is there any discussion this necessary?
2)24VDC supplies in the IO chassis are switching supplies. I asked about this and learned that Downs tested them for noise and found them adequate.