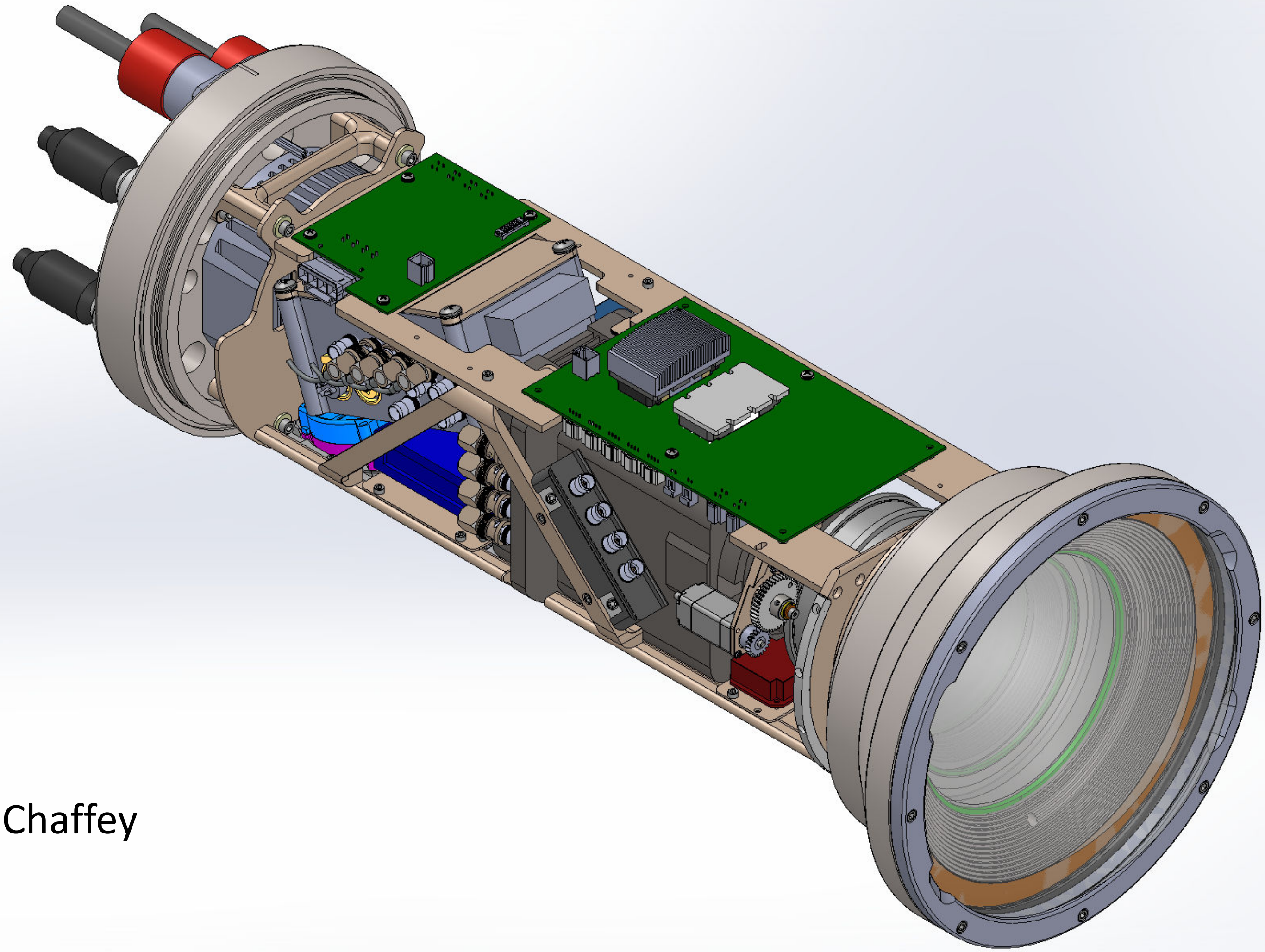
i2MAP Dorado Camera Chassis & Electronics Critical Design Review



Mark Chaffey

Scientific Requirements

The goal of the i2MAP project is to develop an autonomous imaging system that will allow us to automate the midwater time-series data collection process; to shift from ROVs to AUVs.

Basic scientific requirement: To build a system capable of collecting video transecting imagery and environmental data of the quality of that currently collected with the ROVs, or better.

ROV transecting data is currently collected under the following conditions:

- Video quality = 1080i, 30 fps
- Wide field of view (~85^{o} horizontal)
- Adequate and even lighting throughout the field of view
- 120 minutes of video storage (11 depths x 10 minute transect each + leader/trailer)
- Speed: 1.0 knots (~55 cm/sec)
- Environmental sensors:
  - CTD (salinity, temperature and depth)
  - Oxygen sensors x2 (dissolved O2 concentration)
  - Transmissometer, 25 cm (water clarity/relative concentration of particulates in water)

Functional Requirements

(see full text in 901209 project folder)

- The AUV transecting imaging system must replicate the existing ROV based quantitative mid-water transects such that the results of the transects can be compared in a scientifically valid way.
- Maintain the current image data processing and video annotation chain OR create a new processing chain that can be executed with a similar degree of complexity and effort.
- Provide for simultaneous operation with an environmental sensing package (CTD, oxygen X 2, and transmissometer sensors) comparable with that of the ROVs.
- Meet the weight, balance, interface and configuration requirements of a Dorado AUV payload such that extraordinary measures are not required for routine AUV operation.
- Be installed and removed from the AUV Dorado with a minimum of effort, consistent with similar nose cone payloads.

BLUE = Relevant to camera electronics review

Design Requirements

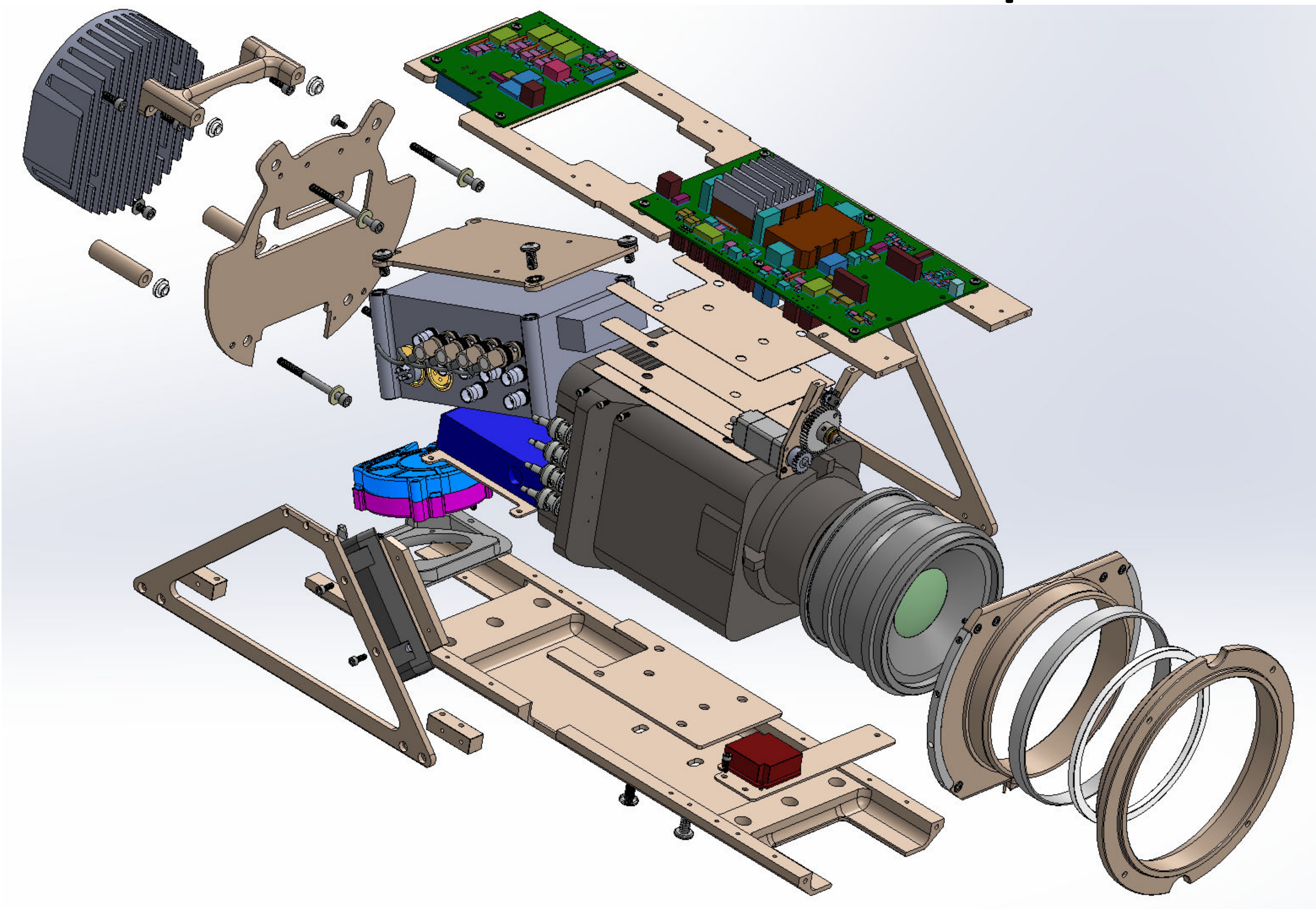
(see full text in 901209 project folder)

- Capture format. The imaging system must capture in a progressive scan format with a minimum resolution of 1920x1080 4:2:2 format at 10 bits at 60 frames per second or greater (1080 60P) for 120 minutes.
- The video records must include SMPTE timecode data that is synchronous with the environmental instrumentation data.
- Depth of field. The imaging system shall allow the identification of small plankton at a range from 0.1 to 2.5 meters from the camera dome with the camera lens in a fixed focus position. Note: it is desirable but not required that the camera system be able to image objects further from the camera than 2 meters, ideally out to 10 meters distance.
- Width of field. The lens system shall have at least an 80 degree horizontal viewing angle.
- The light bars shall hold 4 DSPL Sealights in a position that minimizes backscatter and glaring.
- The Dorado camera payload shall provide for simultaneous operation with the standard CTD, oxygen (x2) and 25 cm transmissometer instruments of the CTD AUV OR duplicate these instruments on the camera payload. The data must be available as part of the standard AUV data load path and be accessible to VARS.
- Operate at specific depths from 50 meters to **1500 meters** performing 11 individual transects of 330 meters length.
  - Dorado shall maintain a constant depth during a commanded transect to within +/- 1 meter.
  - Dorado shall maintain a constant pitch angle during a commanded transect of +/- 10 degrees.
  - Dorado shall maintain a constant roll angle during a commanded transect of +/- 20 degrees.
- The electrical interface to the Dorado AUV must be compatible with:
  - 18 to 36 Volts DC, 15 Amperes maximum continuous current. *Note that SeaCon reports 16A*
  - The data interface is 10/100BaseT Ethernet.

Mechanical System Design

- Chassis design overview
  - Material selection
- Positioning tolerance requirements
  - Fore-aft positioning
    - » Rear stand-offs
    - » Front alignment cone
  - Radial alignment
  - Stiffness to prevent sag (tilt effects)
- Effects on tolerances of Thermal changes

Mechanical Overview - Exploded



Material Selection

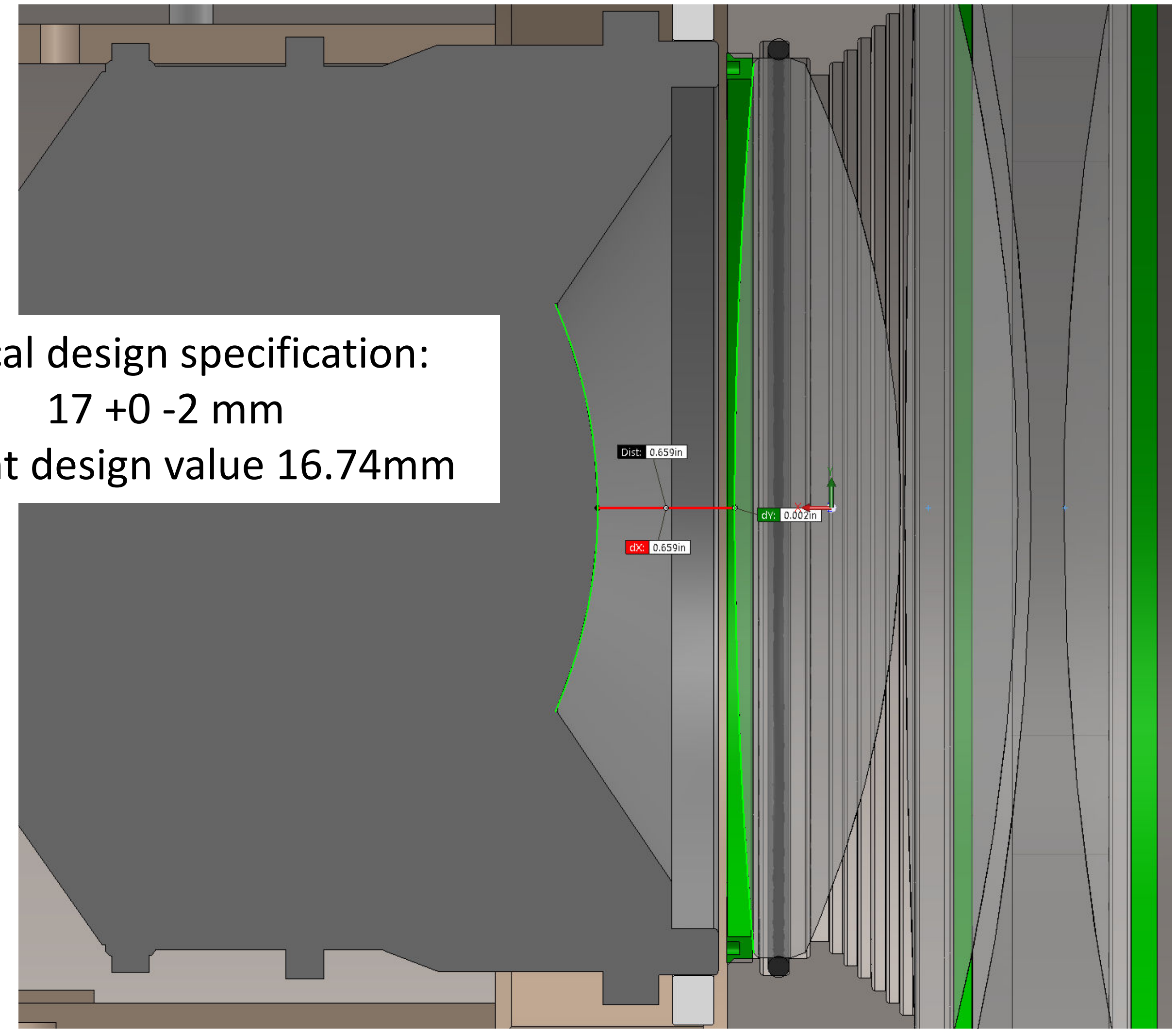
- Polymer parts are specified for low outgassing properties:

MATERIAL	Total Mass Lost (TML) %	Collected Volatile Condensable Material (CVCM) %	Water Vapor Regained (WVR) %
DELRIN 107 BLACK	0.78	0.10	0.20
PEEK (POLYETHERRTHERKEYTONE)	0.14	0.00	0.05
STRATASYS POLYCARBONATE PC10	0.17	0.00	0.14
STRATASYS ULTEM™ 9085	0.41	-0.10	-0.37

Critical Mechanical Tolerances

- Camera lens to port adapter optics distance.
  - Effects of thermal expansion.
- Camera lens and imager axial alignment with port adapter optics.
- Mating tolerance of chassis during housing closure.

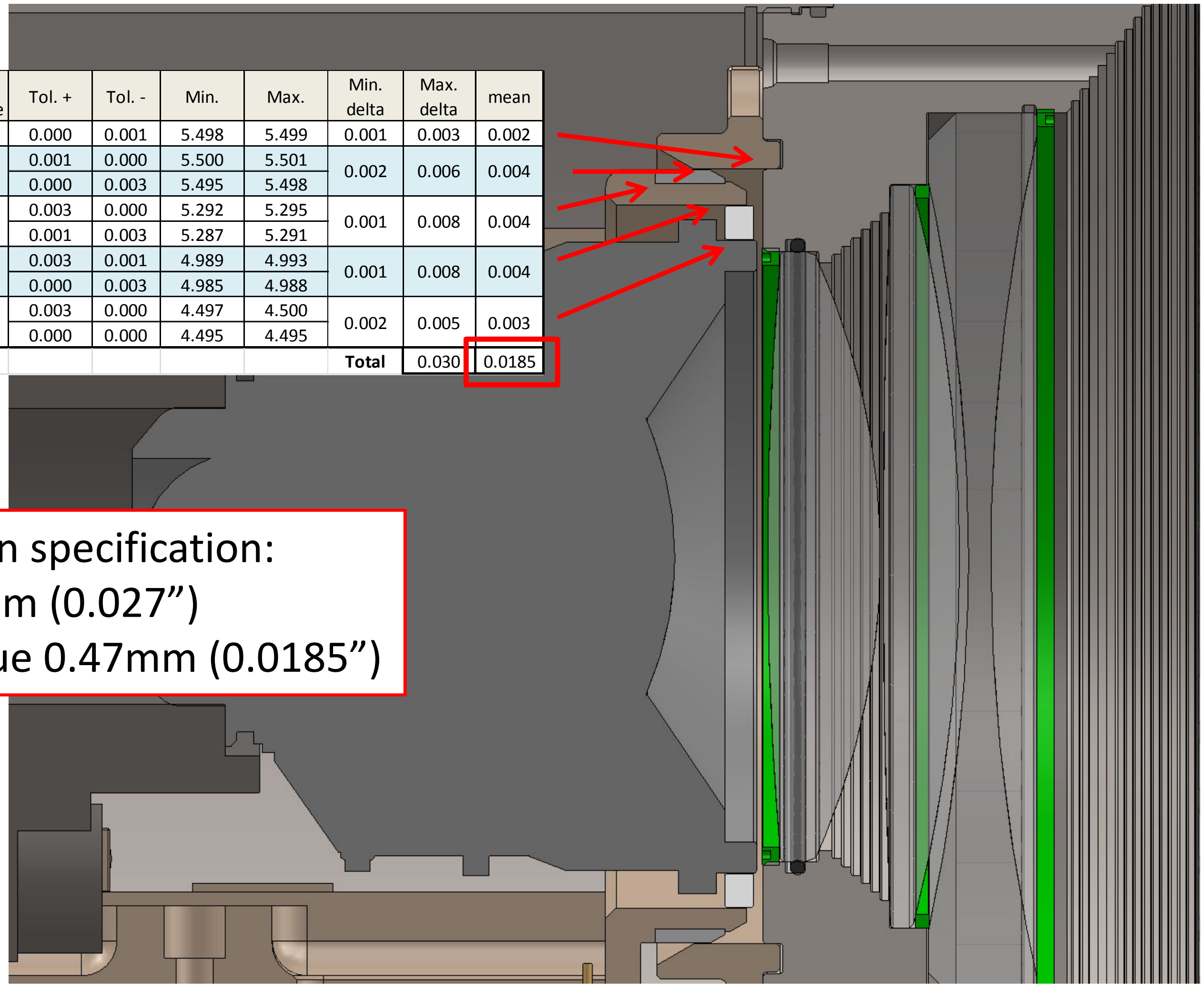
Critical Tolerances – Camera Lens to Port Adapter Lens



Optical design specification:
17 +0 -2 mm
Current design value 16.74mm

Critical Tolerances – Camera Axial Alignment with Port Adapter

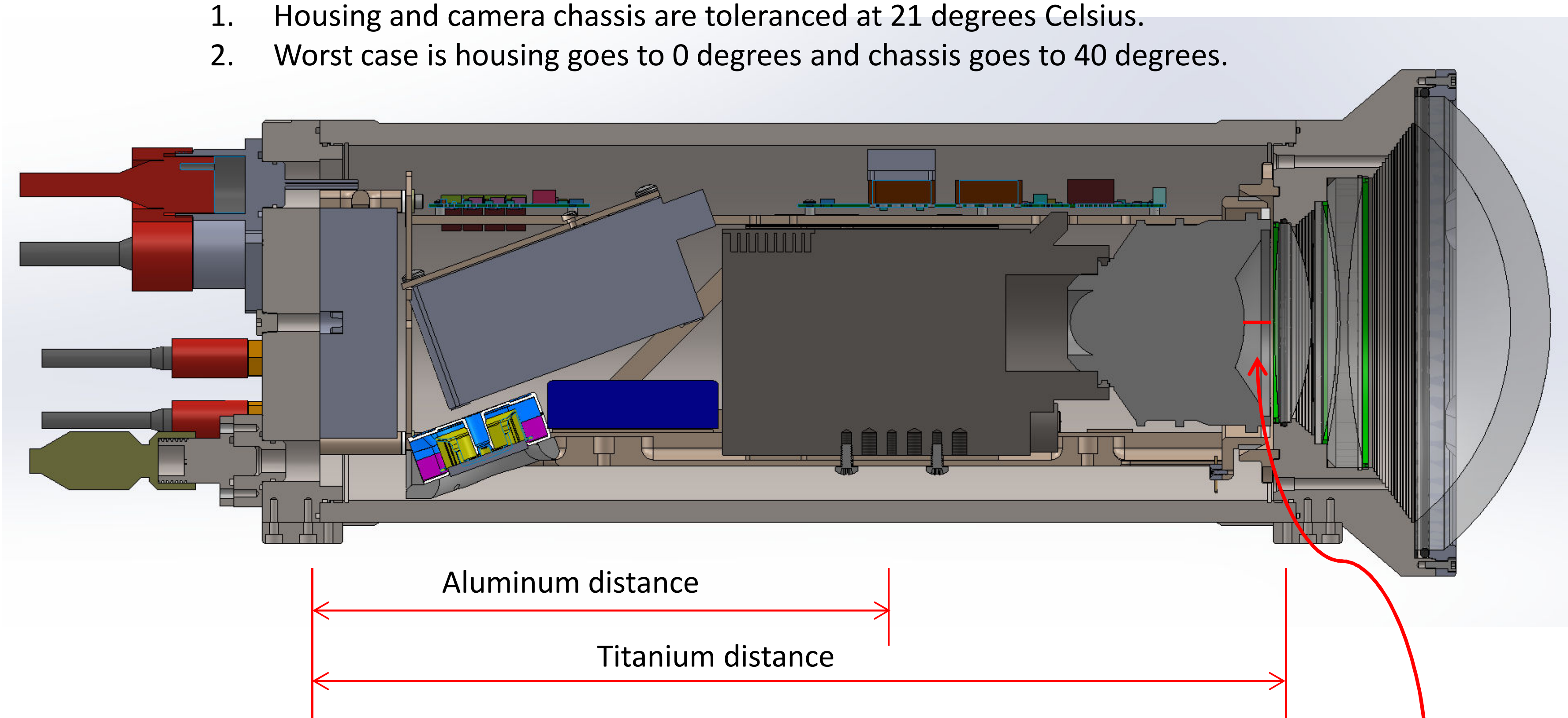
Lens Axial Tolerance	Nominal	Nominal clearance	Tol. +	Tol. -	Min.	Max.	Min. delta	Max. delta	mean
Port adapter ring ID	5.499	0.001	0.000	0.001	5.498	5.499	0.001	0.003	0.002
Port side alignment cone ID	5.500	0.002	0.001	0.000	5.500	5.501	0.002	0.006	0.004
Cone insulator OD	5.498		0.000	0.003	5.495	5.498			
Cone insulator ID	5.292	0.002	0.003	0.000	5.292	5.295	0.001	0.008	0.004
Chassis side alignment cone OD	5.290		0.001	0.003	5.287	5.291			
Chassis side alignment cone ID	4.990	0.002	0.003	0.001	4.989	4.993	0.001	0.008	0.004
Lens support ring OD	4.988		0.000	0.003	4.985	4.988			
Lens support ring ID	4.497	0.002	0.003	0.000	4.497	4.500	0.002	0.005	0.003
Lens OD	4.495		0.000	0.000	4.495	4.495			
							Total	0.030	0.0185



Optical design specification:
+/- 0.7 mm (0.027”)
Current design value 0.47mm (0.0185”)

Critical Tolerances – Thermal Changes

Assumptions:
1. Housing and camera chassis are toleranced at 21 degrees Celsius.
2. Worst case is housing goes to 0 degrees and chassis goes to 40 degrees.

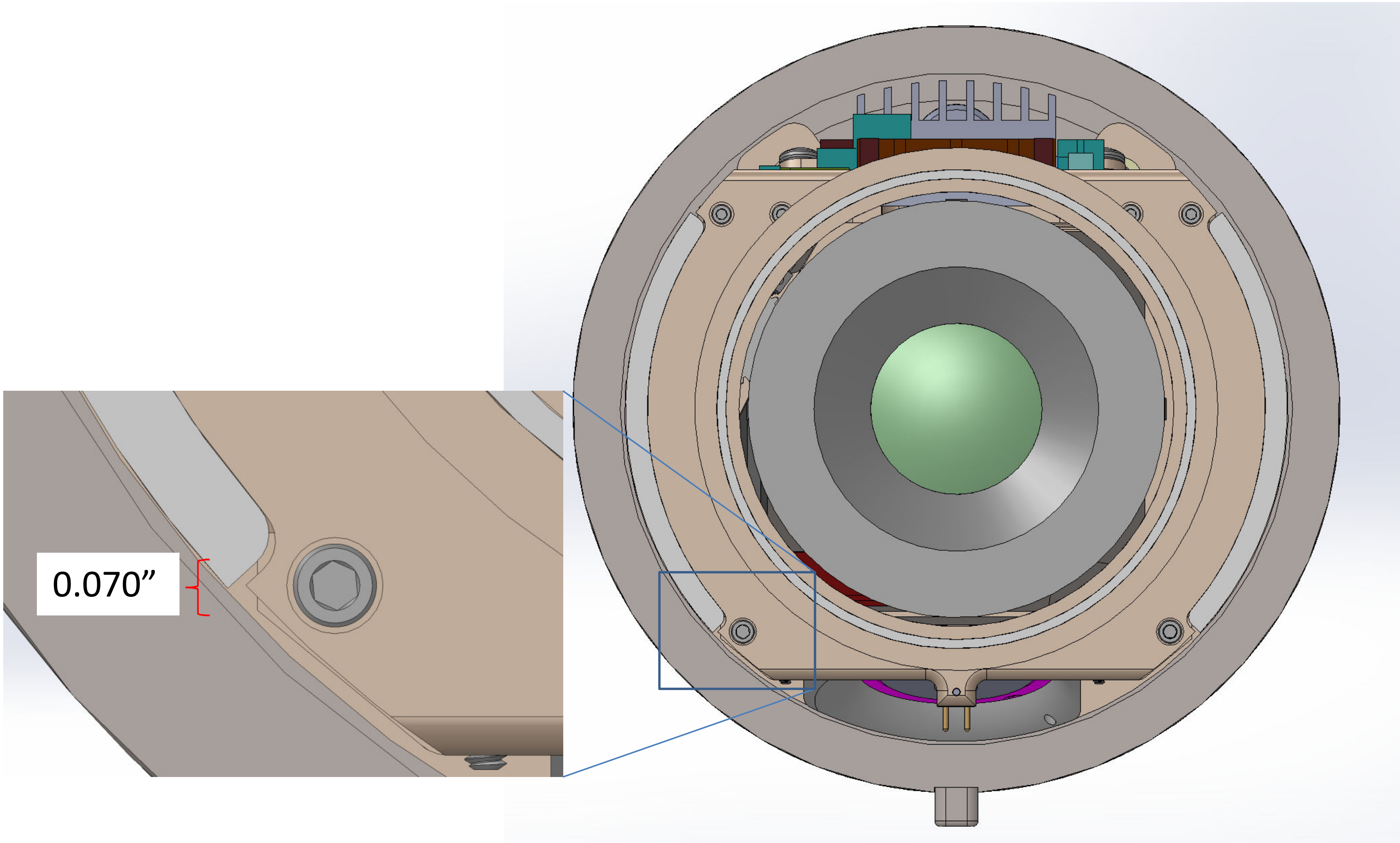


Initial spacing (mm)	16.74
Worst case (mm)	15.64963896
Specification is 17mm +0 -2, minimum spacing =	15mm

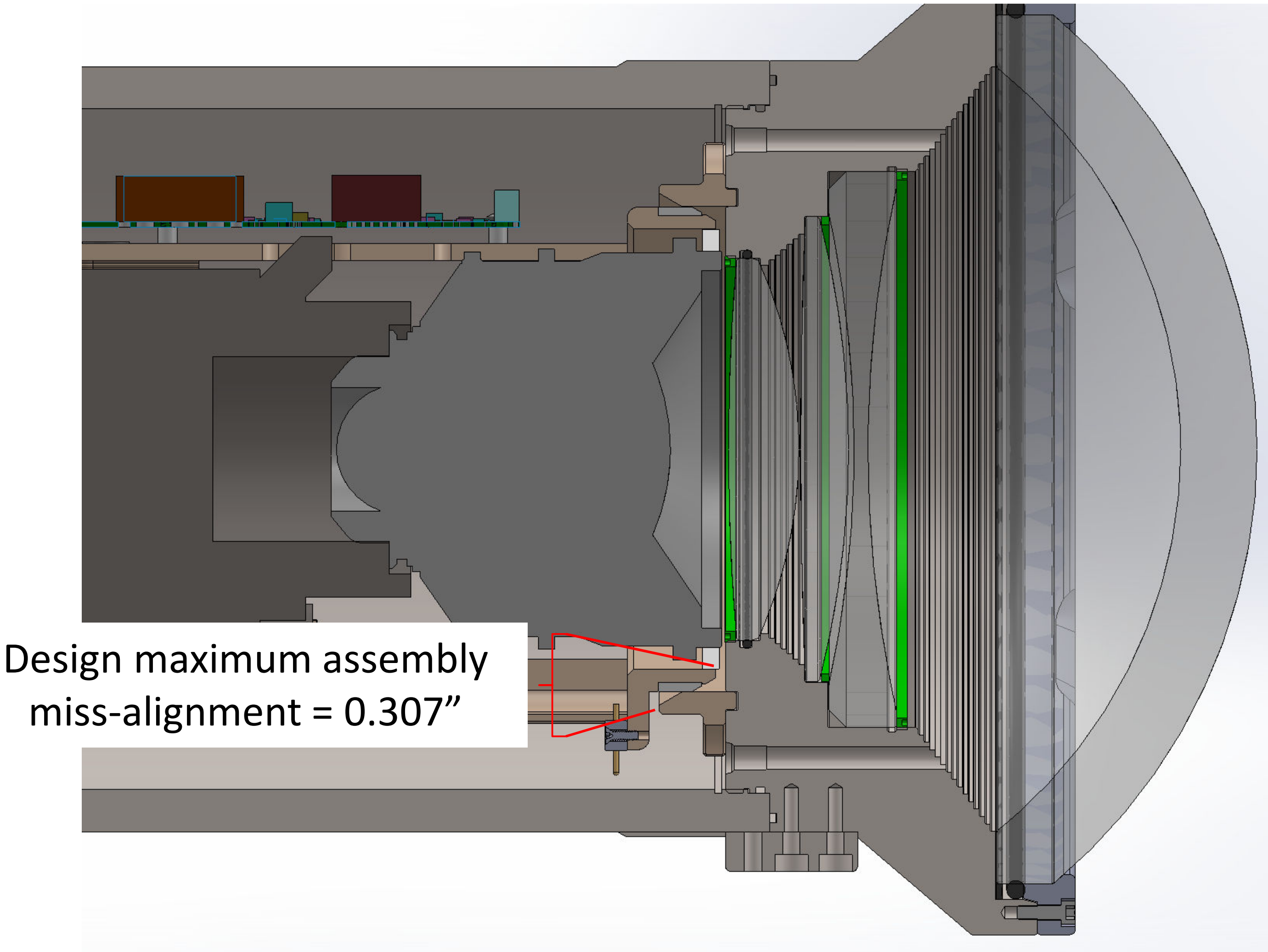
Thermal Calculation

Ti Housing length (in.)	20.85	529.59	mm
Al chassis length (in.)	12.5	317.5	mm
Length diff. @ 21C	8.35	212.09	mm
Starting temperature (celsius)	21		
Chassis highest (celsius)	40		
Housing lowest (celsius)	0		
Aluminum expansion coefficent (mm/mm deg. C)	0.0000222		
Titanium expansion coefficent (mm/mm deg. C)	0.000086		
Worst case chassis length calculation			
Temperature increase delta (celsius)	19		
Change in length (mm)	0.1339215		
Total length when hot	317.6339215		
Worst case housing length calculation			
Temperature increase delta (celsius)	-21		
Change in length (mm)	-0.95643954		
Total length when hot	528.6335605		
Length difference at worst case	210.999639		
Change at worse case (mm)	-1.09036104		
Initial spacing (mm)	16.74		
Worst case (mm)	15.64963896	OK!	
Specification is 17mm +0 -2, minimum spacing =	15mm		

Critical Tolerances - Vertical Clearance



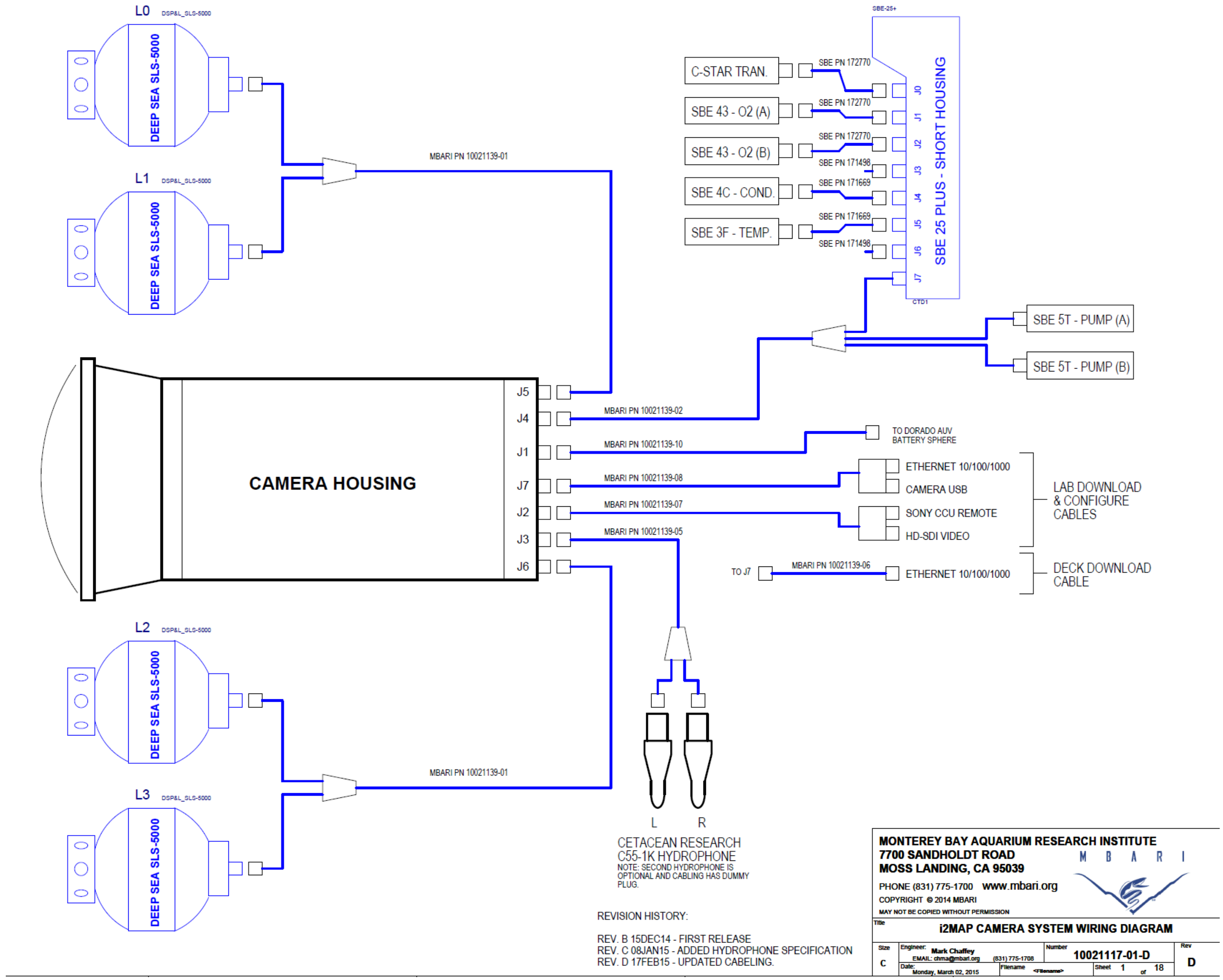
Critical Tolerances – Vertical Clearance



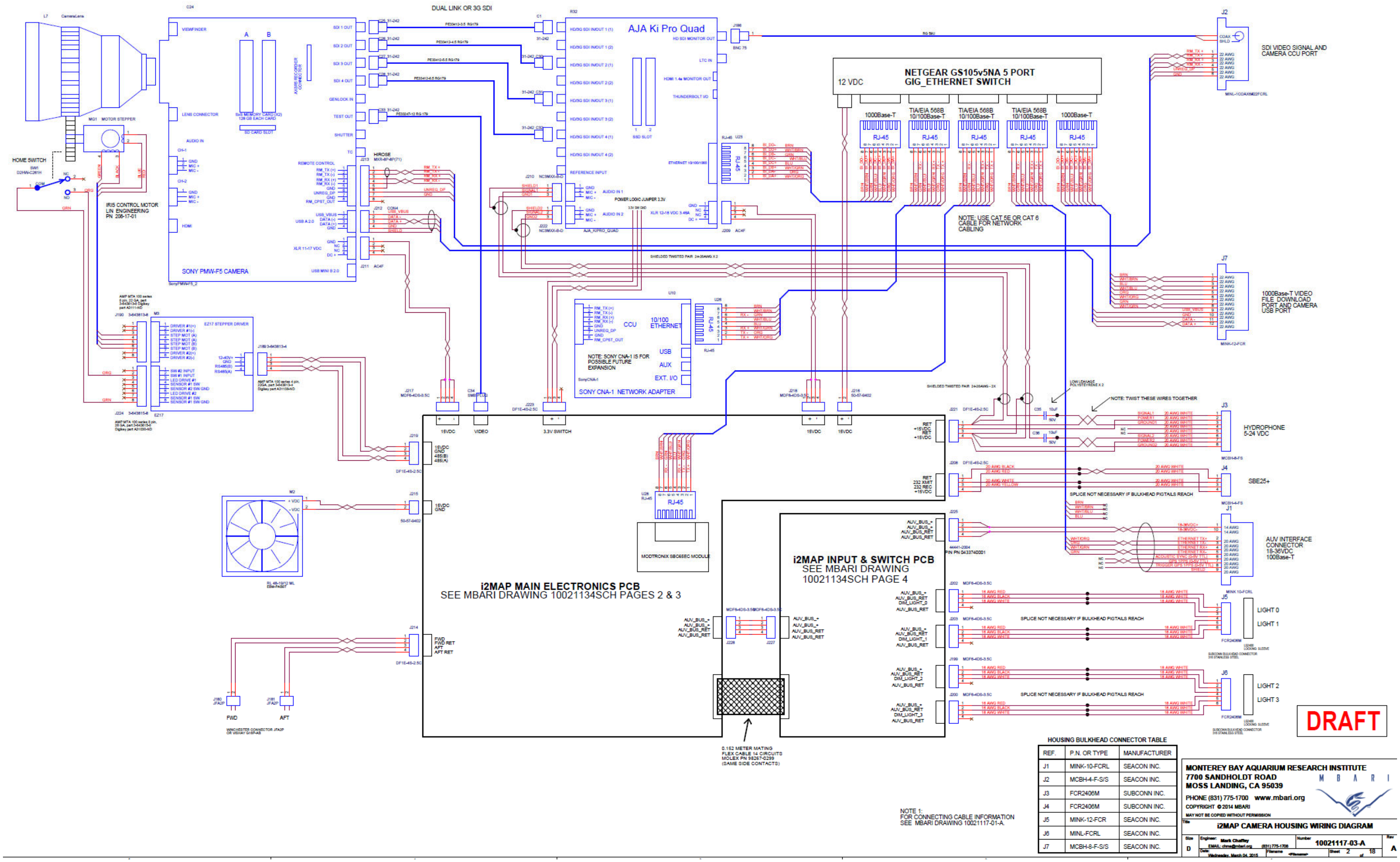
Electrical System Design

- AUV wet wiring
- Camera housing internal wiring
- Input & light switching printed circuit board
  - Current limits & fault reporting
    - MOSFET AUV BUS switches and PCB traces
  - Thermal analysis
    - High current switches

i2MAP System Wiring



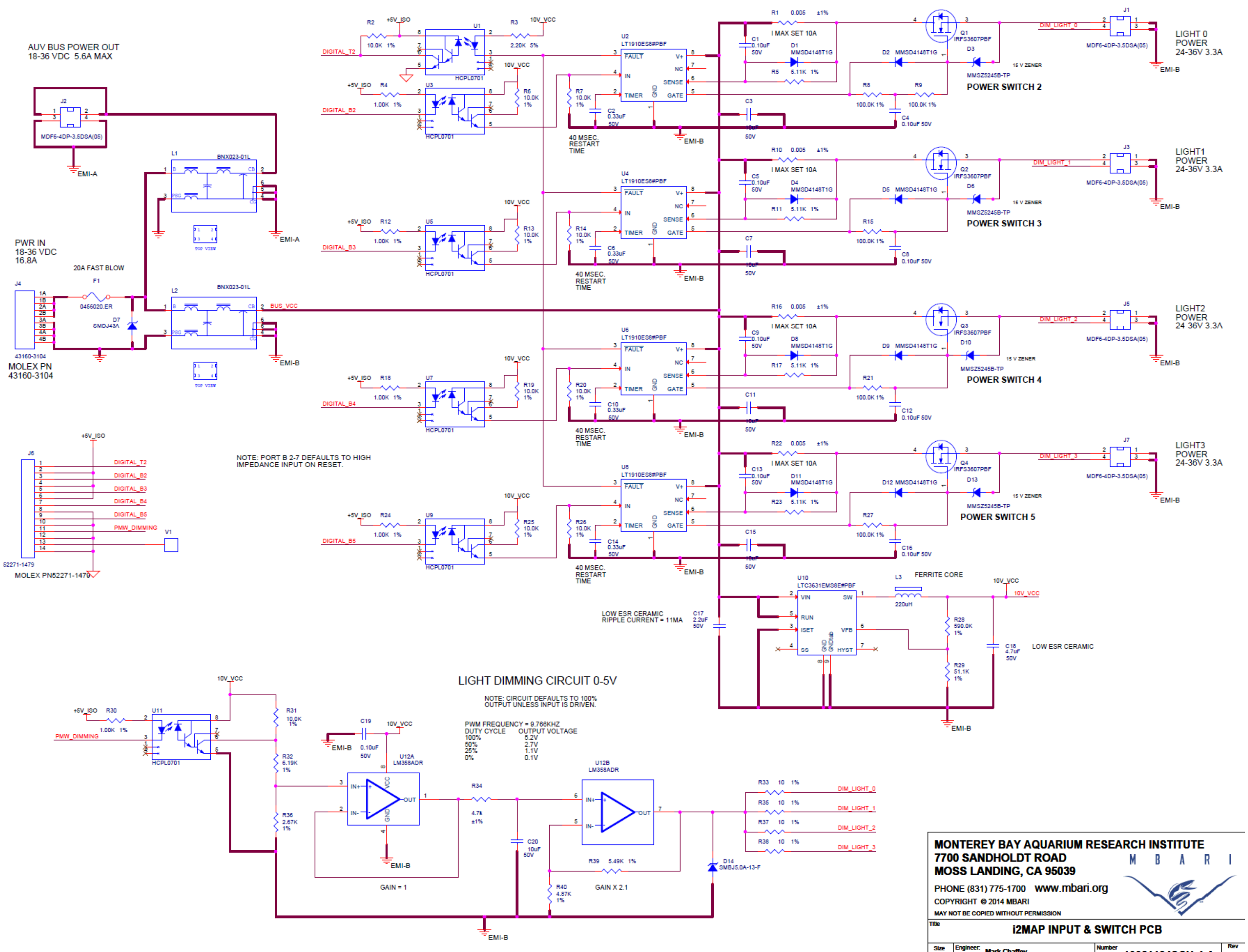
Camera Housing Internal Wiring



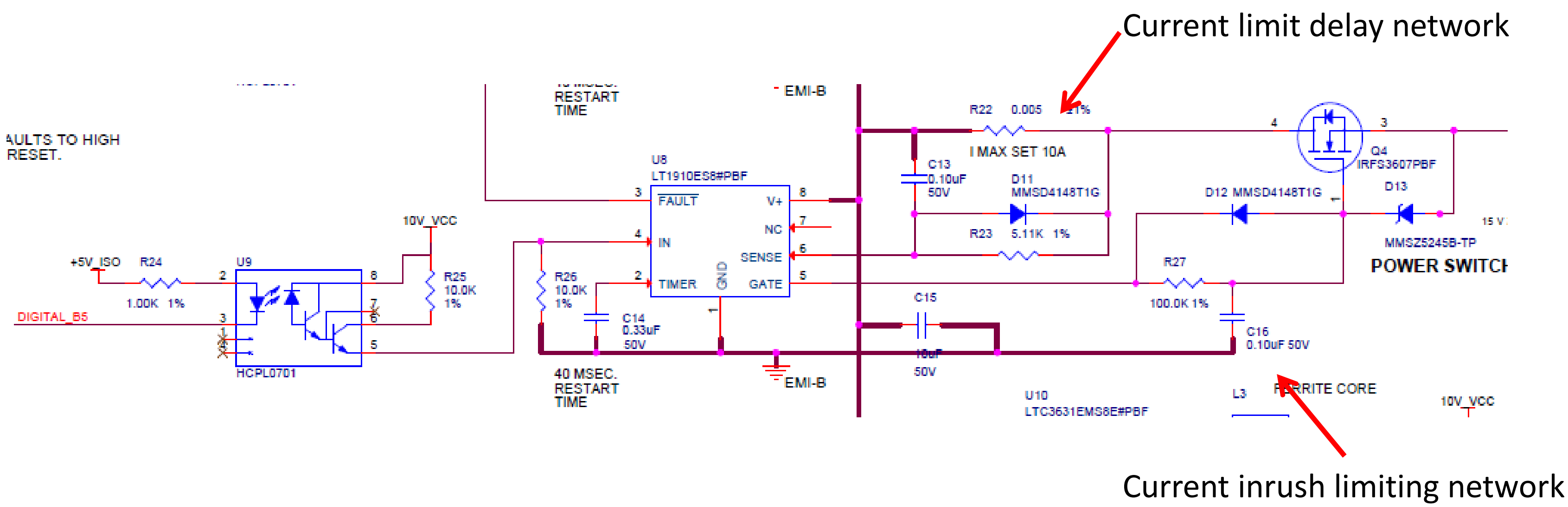
HOUSING BULKHEAD CONNECTOR TABLE

REF.	P.N. OR TYPE	MANUFACTURER
J1	MINK-10-FCRL	SEACON INC.
J2	MCBH-4-F-S/S	SEACON INC.
J3	FCR2406M	SUBCONN INC.
J4	FCR2406M	SUBCONN INC.
J5	MINK-12-FCR	SEACON INC.
J6	MINL-FCRL	SEACON INC.
J7	MCBH-8-F-S/S	SEACON INC.

Input & Switching PCB

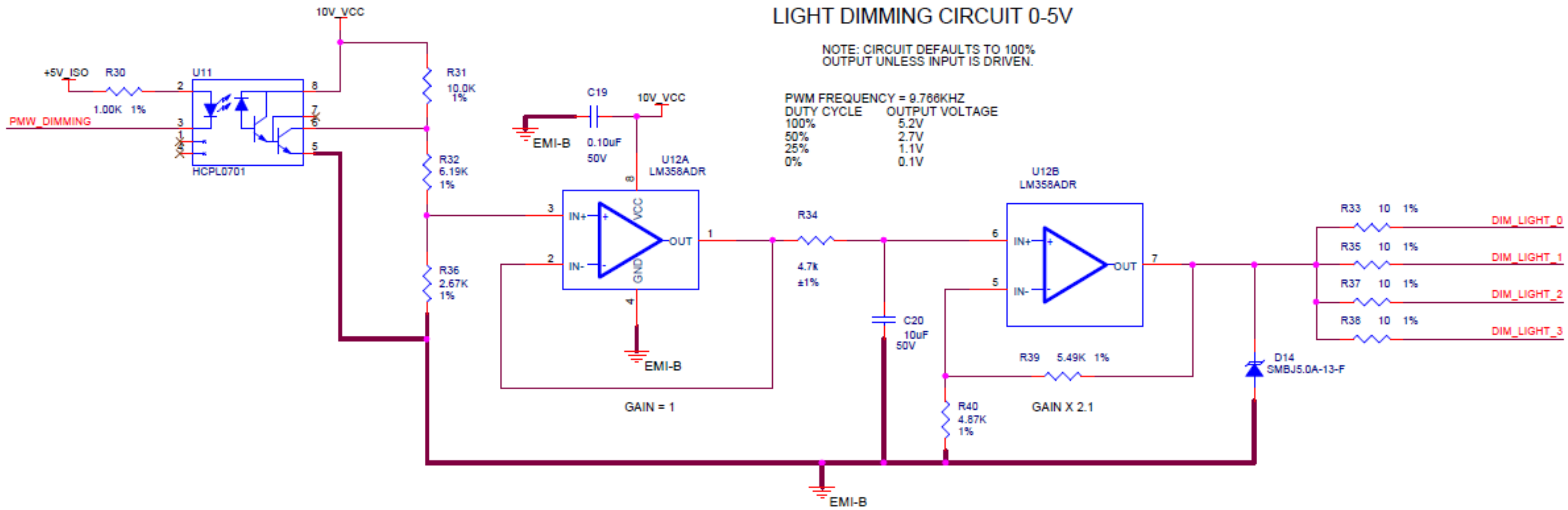


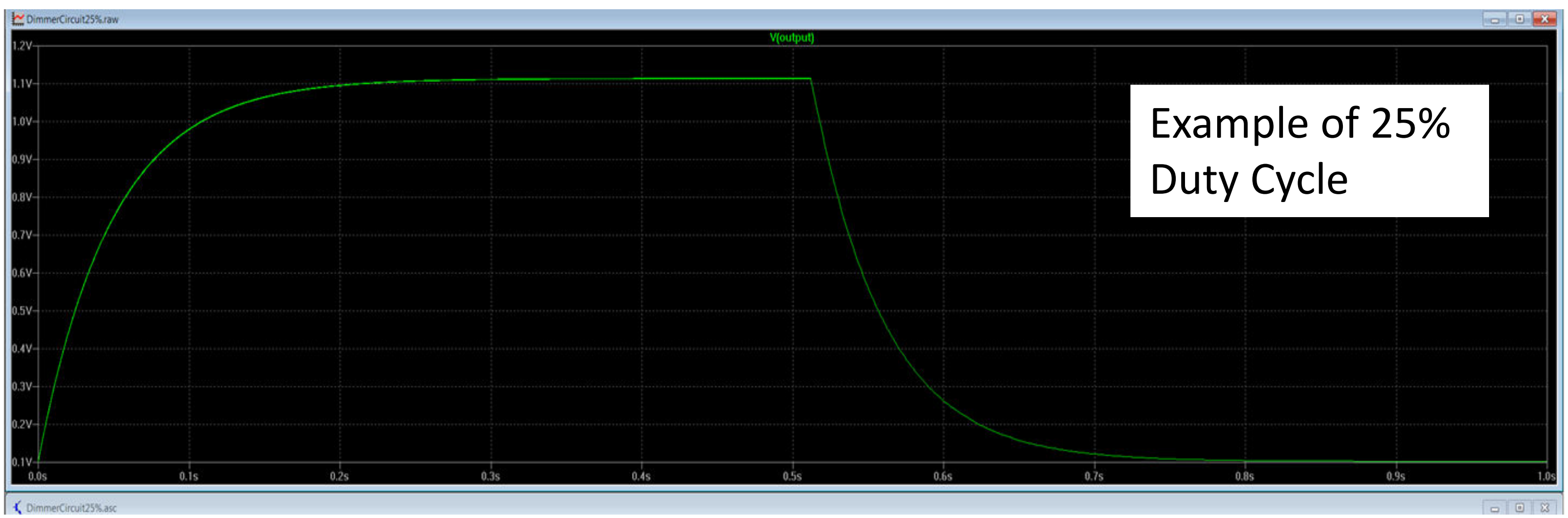
AUV BUS Level Light Switch



- Design current 10A max. (lights are 3.2A).
- MOSFET dissipation 1.35W worst case.
- Worst case junction operating temp. 94C @ 40C ambient.
- Max. allowable MOSFET junction temp. 175C!

Dimming Circuit

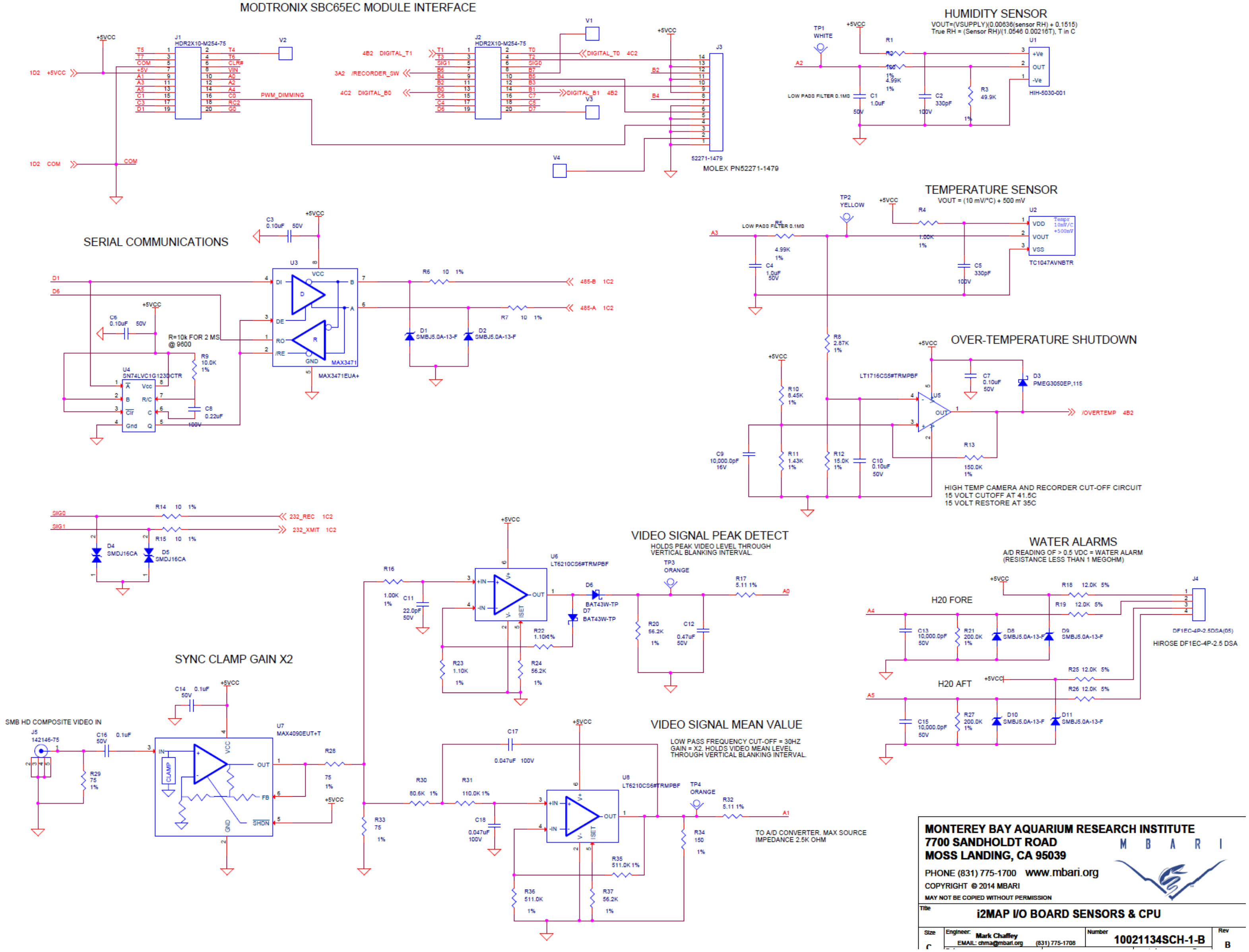




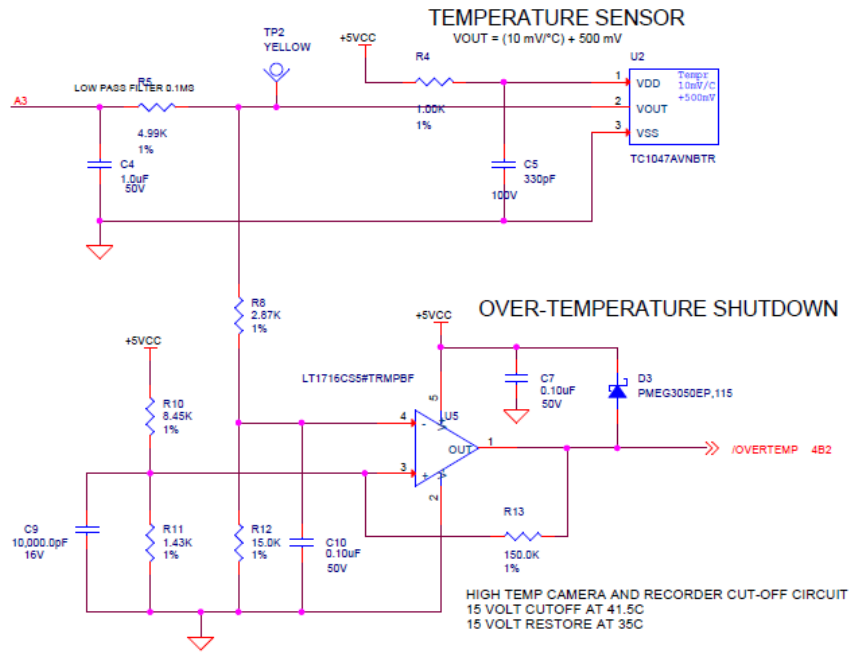
Electrical System Design-continued

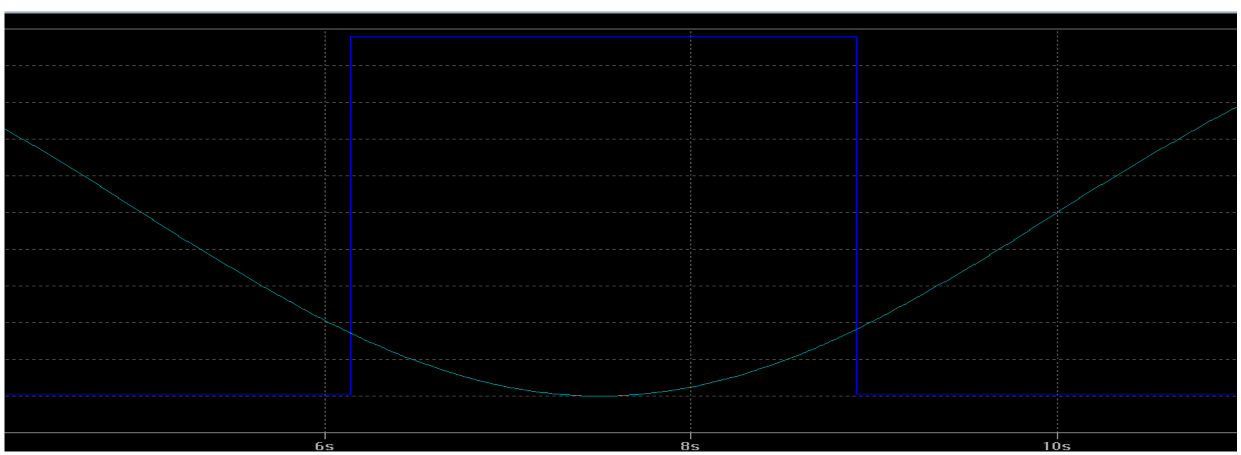
- Main electronics PCB
  - Loads on individual switch circuits
  - Thermal analysis
    - » 15 Volt bus witches
    - » Vicor & heatsink
  - Housing environmental sensors
    - » Overtemperature shutdown circuit
    - » Water alarms
    - » Humidity sensor
  - Video circuits
    - » Video recorder switch
    - » Average and peak detector
  - Modtronics CPU module
    - » I/O pin list

Main Electronics PCB pg.1

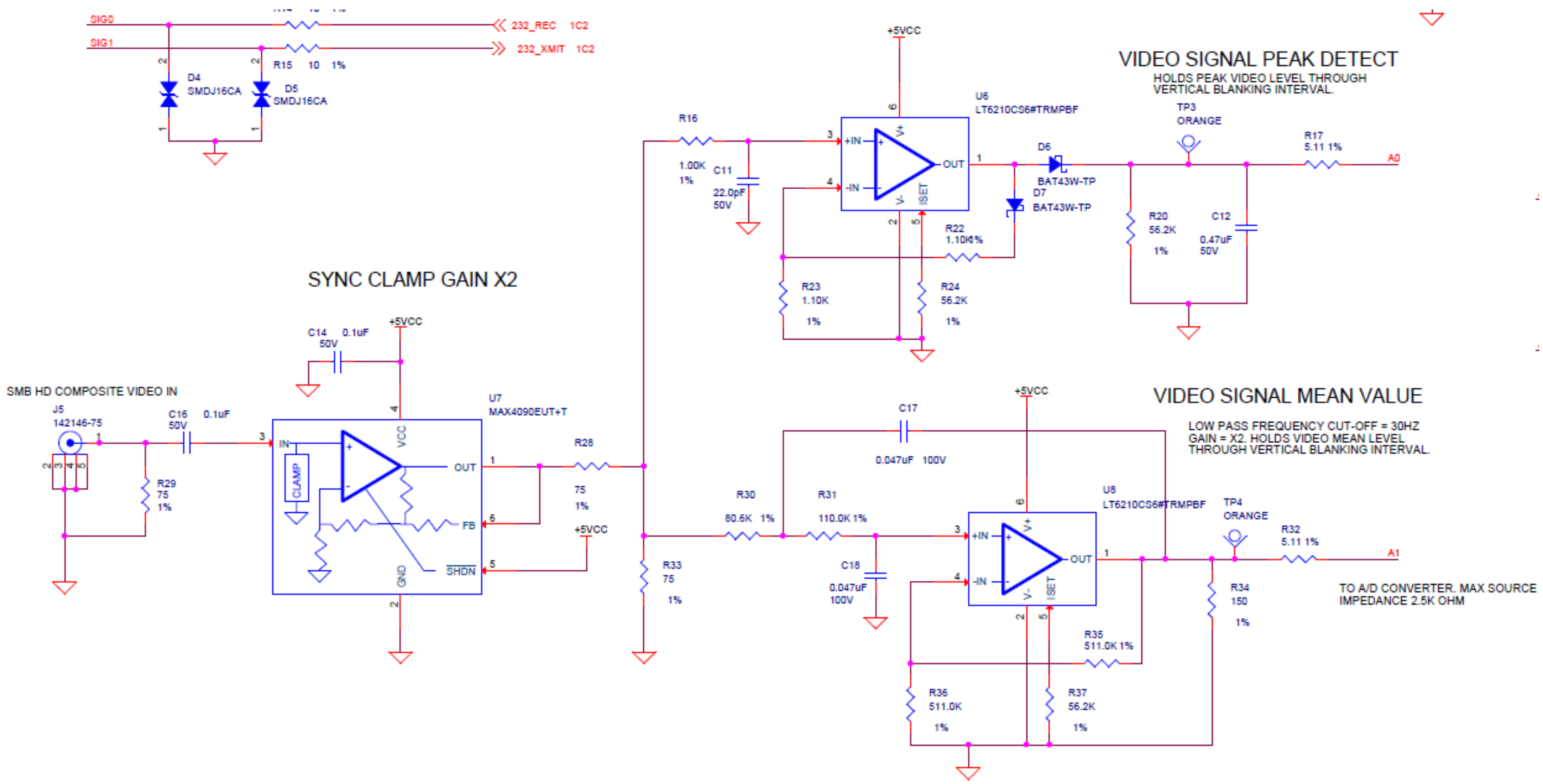


Over Temperature Shut-Down

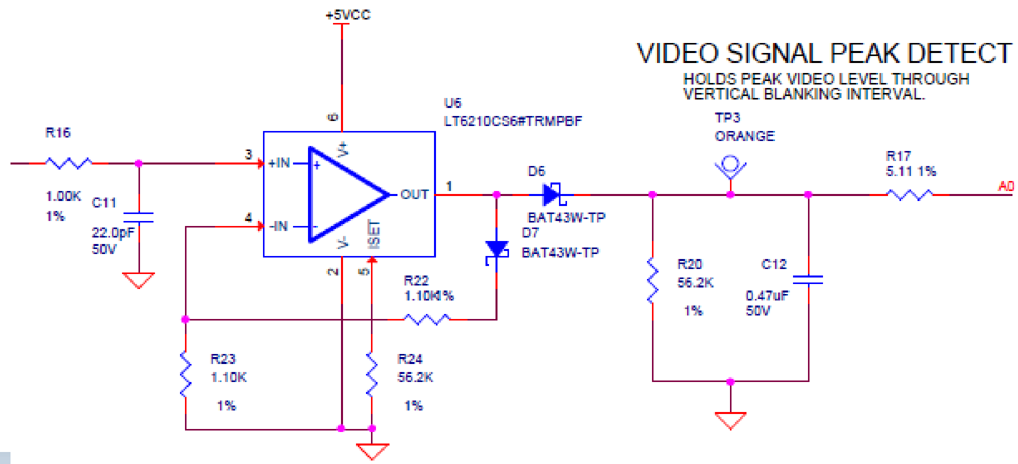


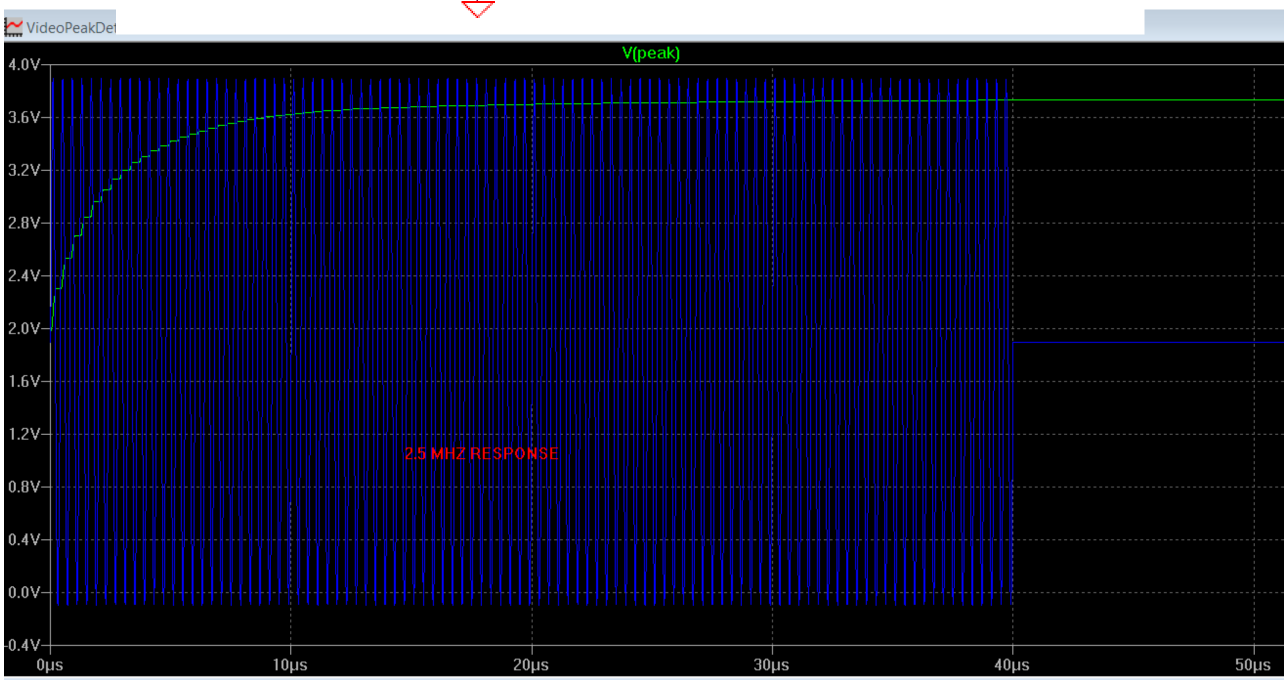


Video Circuits

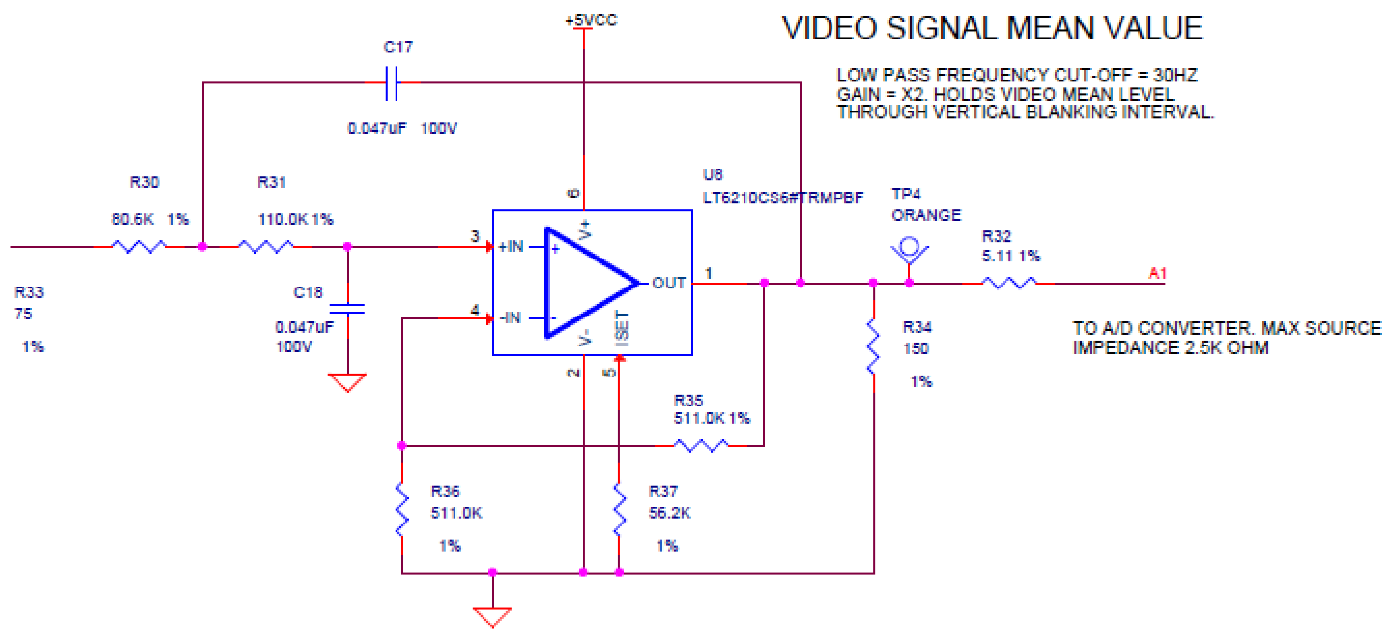


Video Peak Detect





Video Mean Level



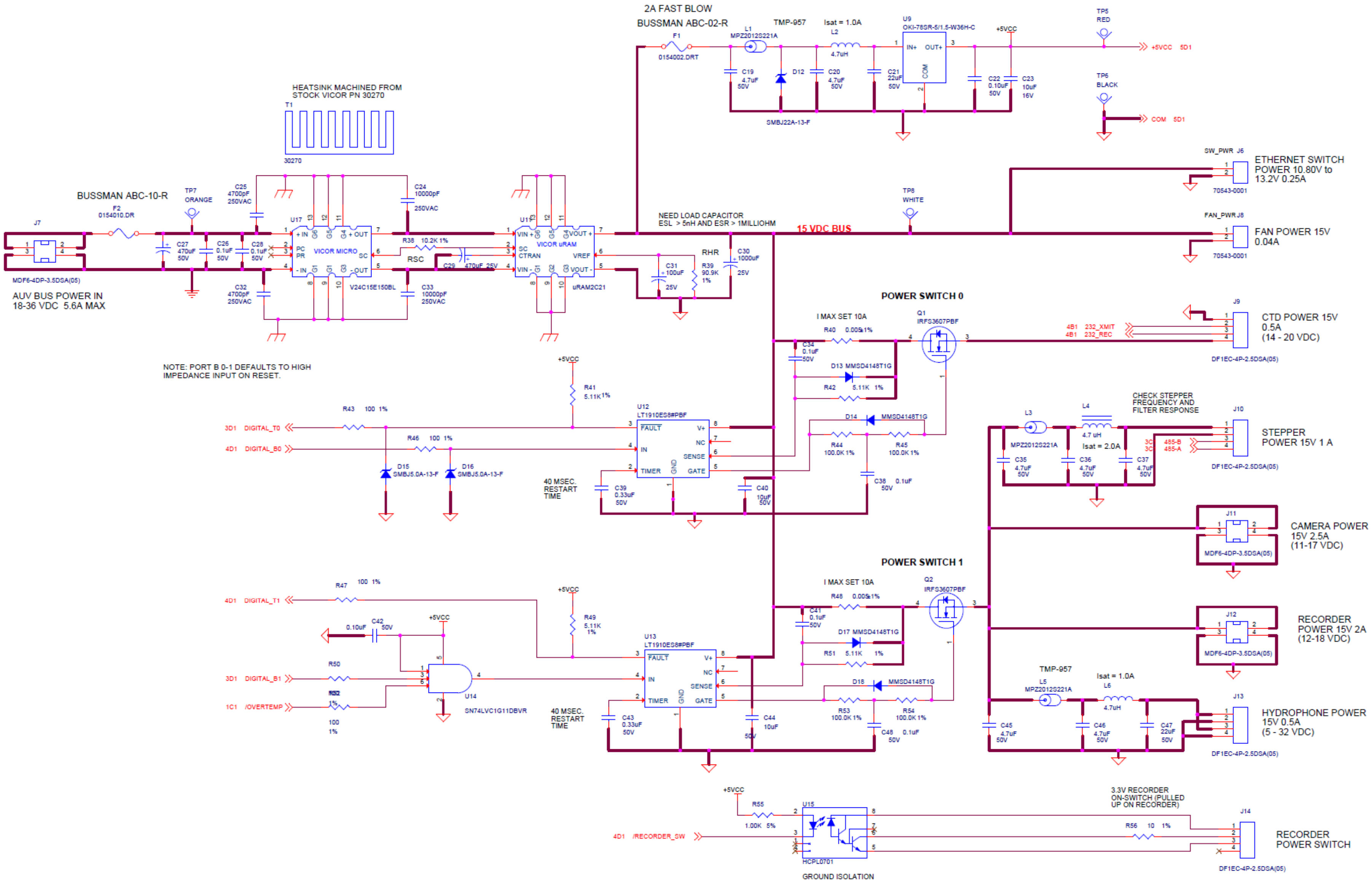
Modtronix SBC65EC Micro

- Simple HTML based API
- Based on PIC18F6627 CPU
- 32 channels of analog and digital I/O
- Two USART interfaces

Modtronix SBC65EC I/O

CON 1 CONNECTOR					CON 2 CONNECTOR				
NAME	PIN	SIGNAL	FUNCTION	Active State	NAME	PIN	SIGNAL	FUNCTION	Active State
T0	2	PIC pin RF0	Power switch SW0 fault input	High	T4	2	PIC pin RF4	Not used	High
T1	1	PIC pin RF1	Power switch SW1 fault input	High	T5	1	PIC pin RF5	Not used	High
T2	4	PIC pin RF2	Power switch SW2 - SW5 fault input	High	T6	4	PIC pin RF6	Over temperature fault input	Low
T3	3	PIC pin RF3	Not used	High	T7	3	PIC pin RF7	Output for power control of the AJA KiProQuad recorder	Driven Low
SIG0	6	USART 1 receive signal - RS232	SBE-25 comms receive (232)		GND	5	Ground	Power return	
SIG1	5	USART 1 transmit signal - RS232	SBE-25 comms xmit (232)		+5V	7	Regulated 0.5A 5V supply	5 V Power input if regulated supply available	
B0	13	PIC pin RB0	Output Switch 0	High	VIN	8	Unregulated input voltage	7-35 V Power input	
B1	14	PIC pin RB1	Output Switch 1	High	CLR#	6	PIC pin /MCLR	Not used	
B2	11	PIC pin RB2	Output Switch 2	Driven Low	A0	10	PIC pin RA0	Analog input peak video level 0-5V	
B3	12	PIC pin RB3	Output Switch 3	Driven Low	A1	9	PIC pin RA1	Analog input mean video level 0-5V	
B4	9	PIC pin RB4	Output Switch 4	Driven Low	A2	12	PIC pin RA2	Analog input for humidity sensor 0-5V	
B5	10	PIC pin RB5	Output Switch 5	Driven Low	A3	11	PIC pin RA3	Analog input for temp sensor 0-5V	
B6	7	PIC pin RB6 – also used for ICP (1)	Not used		A4	14	PIC pin RA4	Analog input FWD water alarm	voltage > 0.5 V = water
B7	8	PIC pin RB7 – also used for ICP (1)	Not used		A5	13	PIC pin RA5	Analog input AFT water alarm	voltage > 0.5 V = water
C4	17	PIC pin RC4 – port pin assigned for I2C (2)	Not used		C0	16	PIC pin RC0	Not used	
C5	18	PIC pin RC5	Not used		C1	15	PIC pin RC1	PWM output for all light dimming	Not Driven or Driven High = 100% = full pwr
C6	15	PIC pin RC6	Not used, Xmit output for USART 1 (TTL)		C2	18	PIC pin RC2	Not used	
C7	16	PIC pin RC7	Not used, Rec input for USART 1 (TTL)		C3	17	PIC pin RC3 – port pin assigned for I2C (2)	Not used	
D6	19	RG2 – USART2 Receive	Camera Iris controller receive (TTL)		D0	20	RG0	Not used	
D7	20	RG3	Not used		D1	19	RG1 – USART2 Transmit	Camera Iris controller xmit (TTL)	

Main Electronics PCB pg.2



Vicor Power Dissipation

Vicor Module and Power Supply Design & Selection Tools

Overview | Calculators

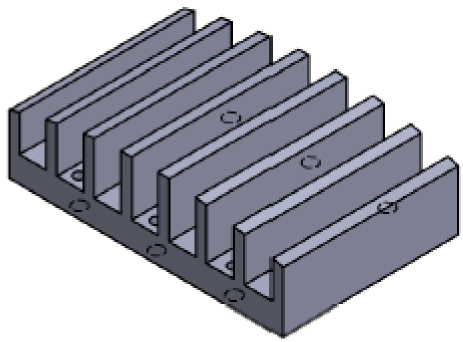
Selected calculator: Thermal issues for heat sink selection

Thermal Calculations

Download Thermal Excel File (Internet Explorer only)
Save to disk before launching Thermal data for Vicor VI-200 / VI-J00 and Maxi, Mini and Micro products series.

	Maximum Output Power	Maximum Thermal Impedance	Maximum Ambient Temperature	Temperature Rise
Output power Clear		85 W	85 W	85 W
Module efficiency Clear	88 %	88 %	88 %	88 %
Dissipation		12 W	12 W	12 W
Input power		97 W	97 W	97 W
Thermal impedance Clear	5.04 °C/W		5.04 °C/W	5.04 °C/W
Max. baseplate temp. Clear	100 °C	100 °C	100 °C	
Max. ambient temp. Clear	40 °C	40 °C		
Reset	Calculate 87 W	Calculate 5.2 °C/W	Calculate 42 °C	Calculate 58 °C

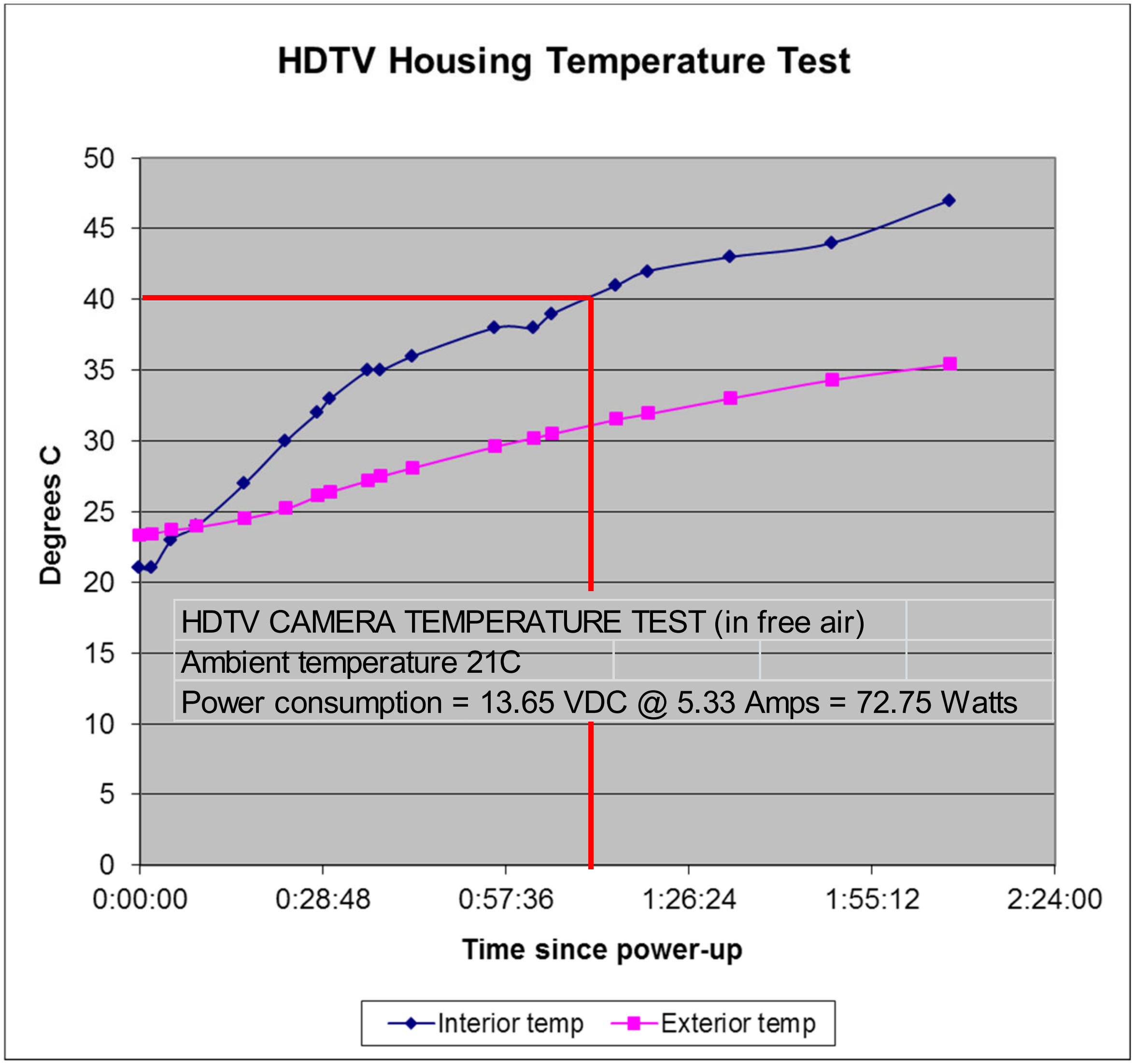
Thermal dissipation is very close or over the limit in still air – depending on air flow for good performance



Micro θba (Baseplate-to-Ambient Thermal Resistance Values) vs. Airflow

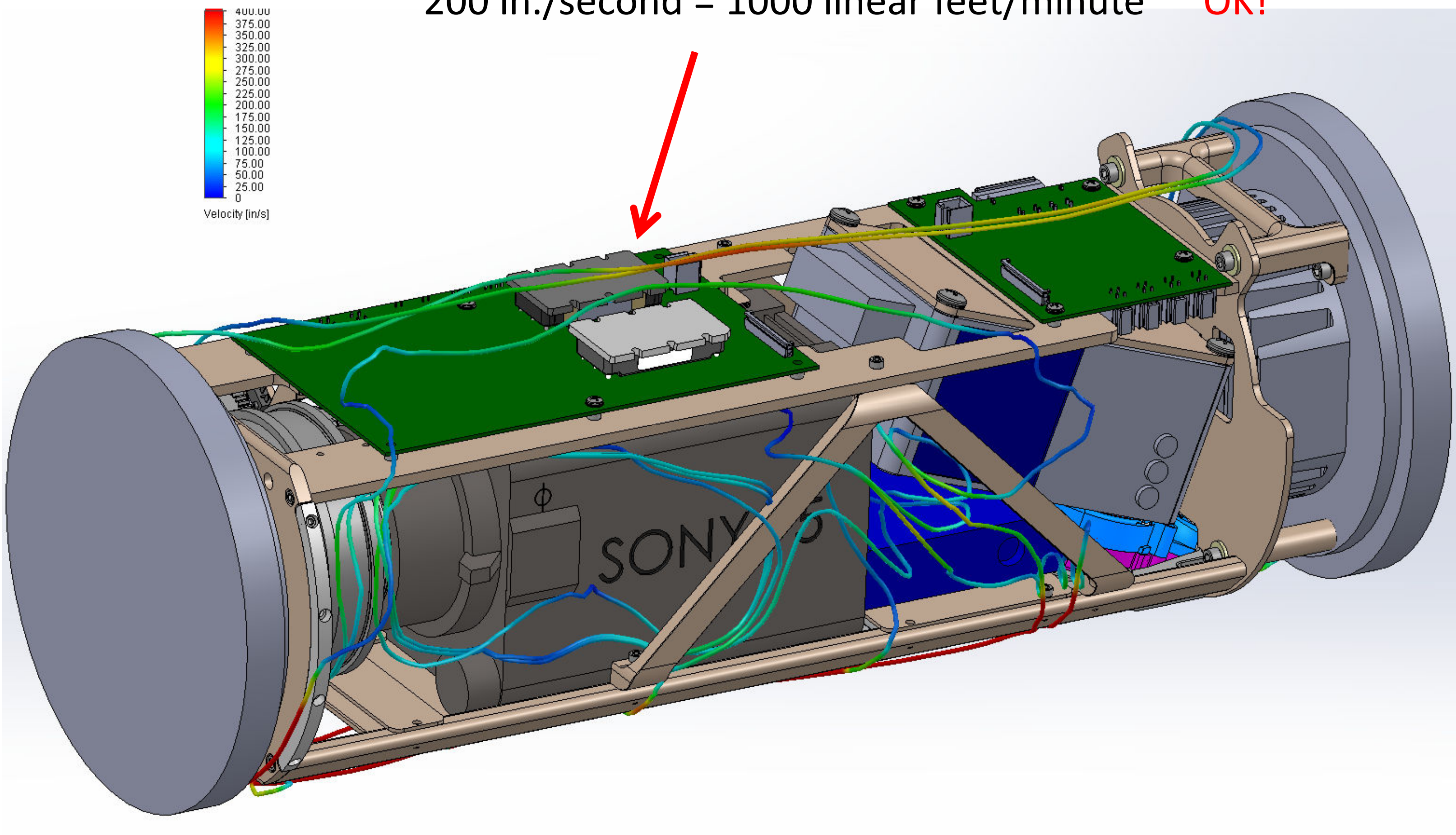
θbs = 0.21°C/W	Baseplate	0.9'' Longitudinal Fins	0.9'' Transverse Fins	0.4'' Longitudinal Fins	0.4'' Transverse Fins
Free Air	10.90	5.37	5.04	7.77	7.76
200 LFM	6.90	2.51	2.31	3.87	3.58
400 LFM	4.78	1.79	1.68	2.68	2.52
600 LFM	3.74	1.42	1.31	2.13	2.01
800 LFM	3.15	1.20	1.10	1.78	1.67
1,000 LFM	2.79	1.06	0.97	1.48	1.45
1,200 LFM	2.49	0.93	0.88	1.32	1.29

HDTV Housing Thermal Testing

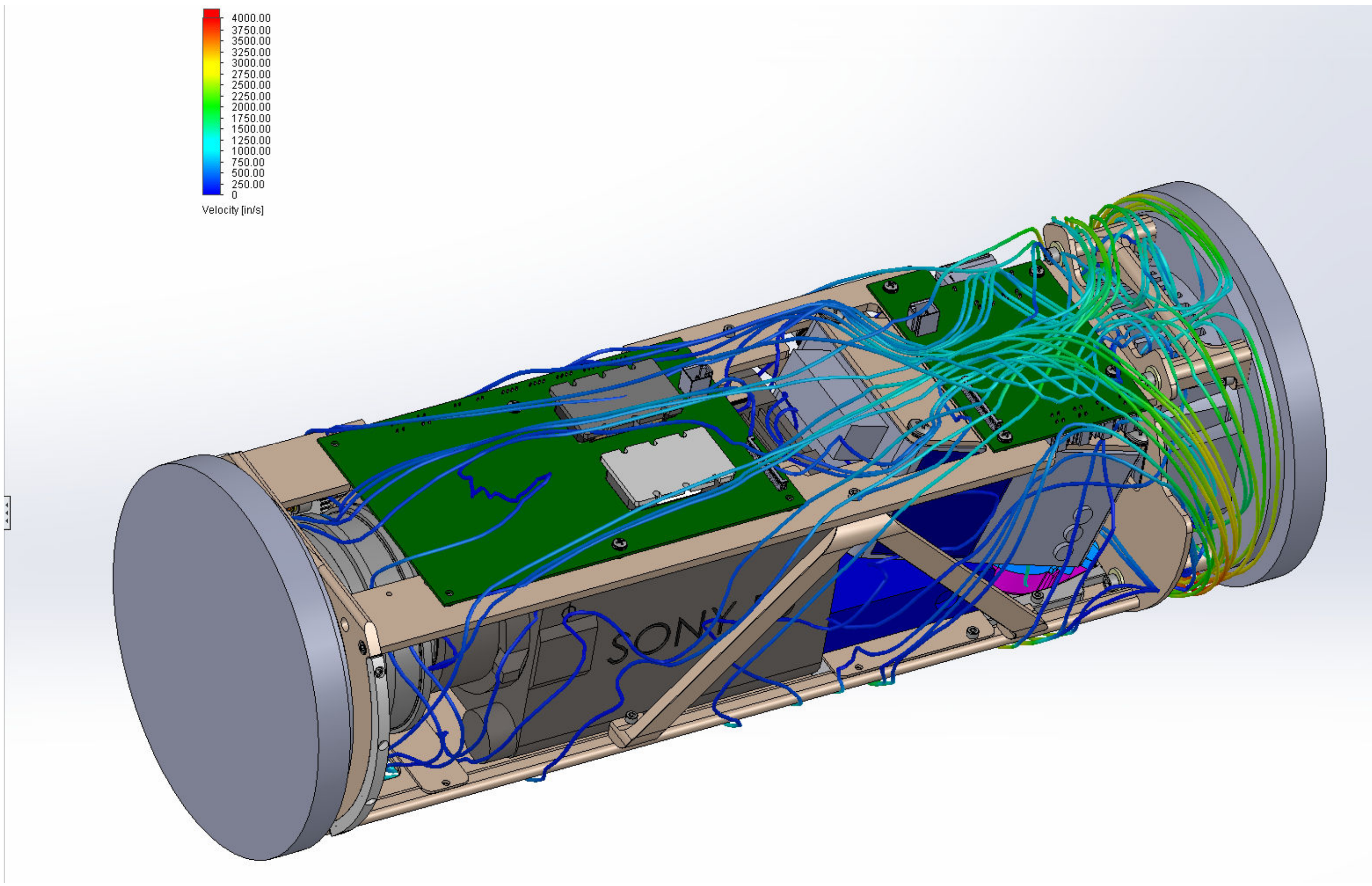


Housing Internal Air Flow (x1)

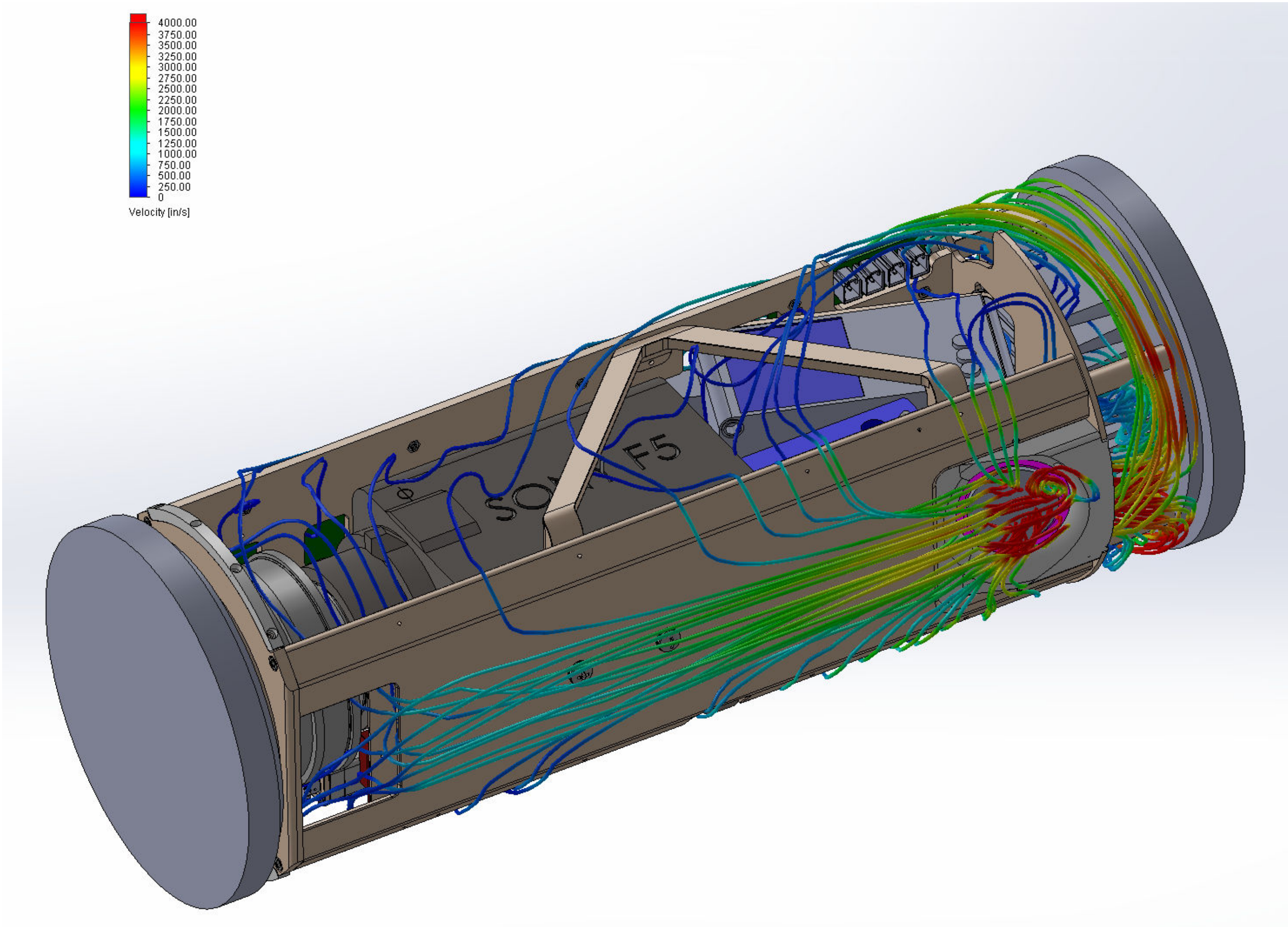
200 in./second = 1000 linear feet/minute OK!



Housing Internal Air Flow (x 100)



Housing Internal Air Flow (x 100)



Electrical System Design-continued

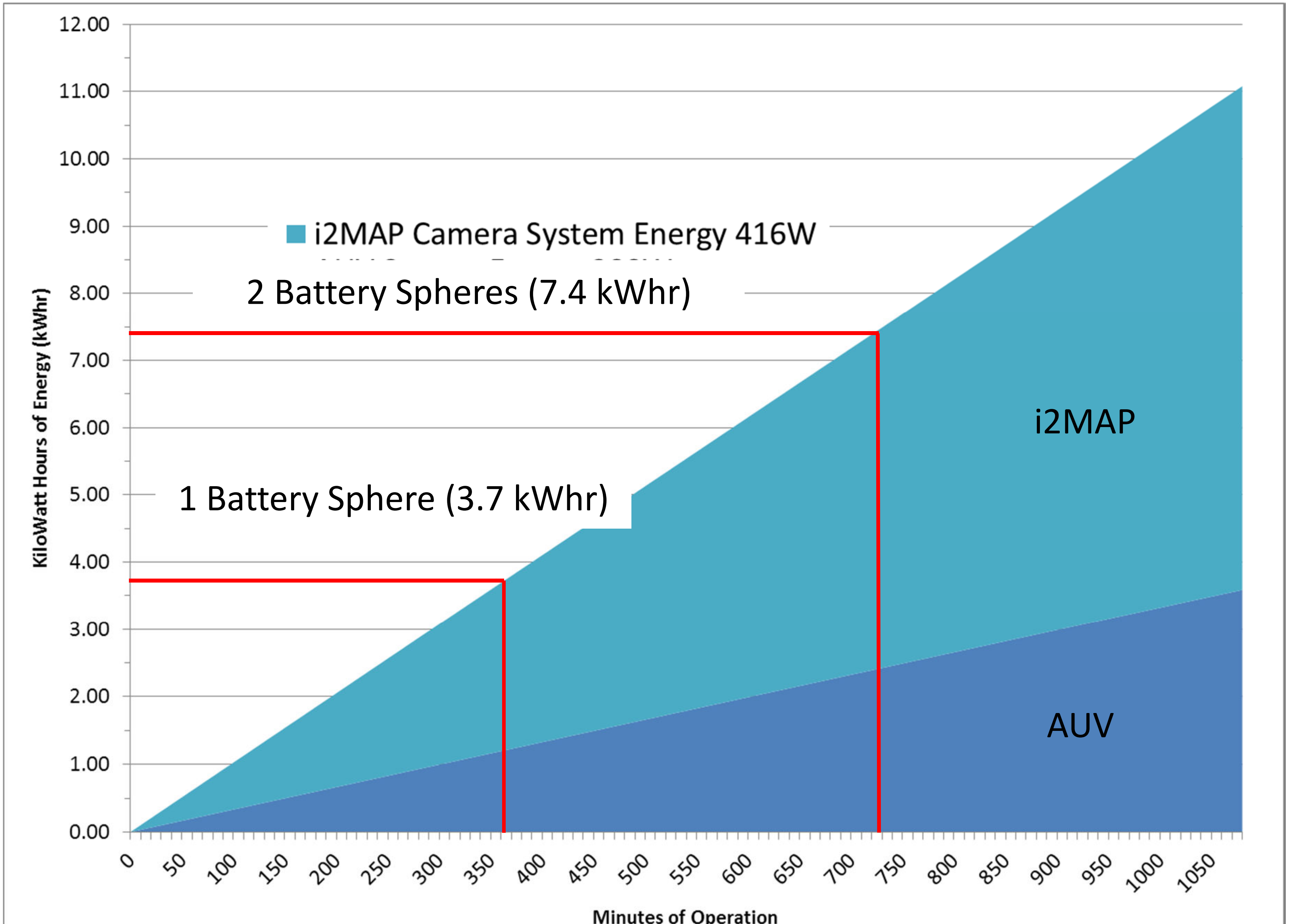
- Energy budget
  - Re-visit AUV energy budget
- AUV and data downloading interface
  - AUV connector
    - Current limit
- CTD and other environmental sensors

i2MAP Payload Energy Budget

Camera module energy budget (Watts)		Device loads	15V Loads	Bus loads			
SLS-5000 LED	4	80		320			
Stepper controller	1	12	12				
Camera	1	24	24				
Video recoder	1	35.5	35.5				
NetGear switch	1	2.7	2.7				
Micro-computer	1	0.5	0.5				
Cooling fan	1	5	5				
Science intruments	1	5	5				
		Sub Total	84.7	320	72	Video switch loads	
Power conversion efficency (%)			88	96.3			
			Total bus load	**416.3**	16.0	Amps Current @ 26V	

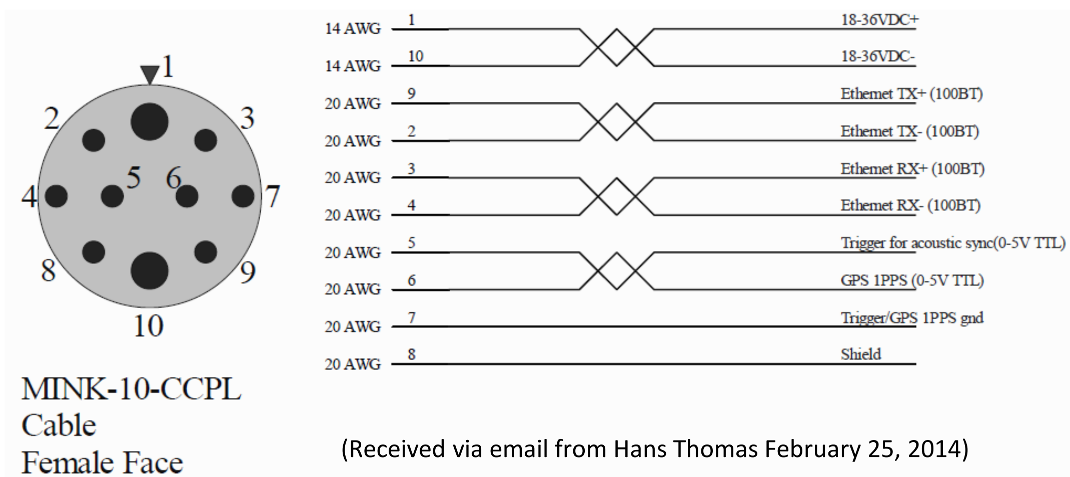
SEE INTERFACE PAGE

Total Energy Use by Dorado (@ 1 m/sec.)



Dorado AUV interface & Power Budget

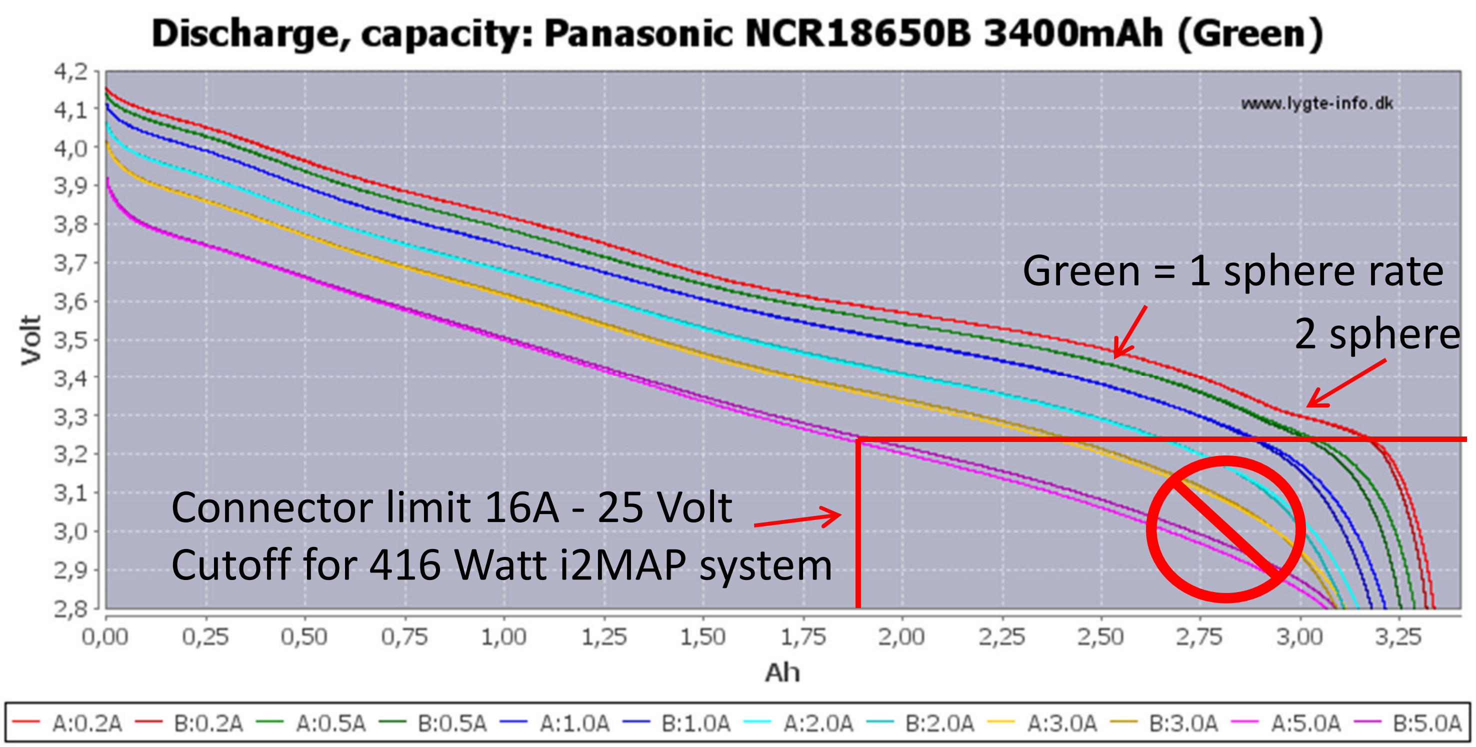
- **Hardware Interface.**
  - The electrical interface to the Dorado AUV must be compatible with:
    - 18 to 36 Volts DC. (new battery will be 20-36V)
    - 16 Amperes maximum continuous current . (SeaCon reports 16A)
  - NOTE: this is 288 Watts at low battery and 576 Watts at high battery. We need about 416 Watts to run 4 lights full power (16A @ 26VDC).
  - The data interface is 10/100BaseT Ethernet.



(Received via email from Hans Thomas February 25, 2014)

i2MAP Limited by AUV Connector Maximum Current

- With 4 x 80 Watt lights we are limited by the Dorado interface connector 16 Ampere maximum at low battery voltages (<26 Volts).
- Required solution:
  - Cut off i2MAP lights or reduce output when AUV battery voltage drops below 26 Volts.
  - This cutoff will not have a significant effect on the mission endurance.



Post-Mission Work Flow