

# The Hat Creek Radio Observatory

## The RFSoC Digitizer Module



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February 8, 2023

## 1 General

This document outlines general information regarding the RFSoC Digitizer Module such as the design, parts, wiring, and cabling. This information is aimed at detailing the entire process of creating an RFSoC Digitizer Module.

The purpose of an RFSoC Digitizer Module is to digitize the analog signals detected by the ATA's antennas. Once digitized, the signals can be saved and analyzed. This digitizer is a replacement for the ATA's previous digitizers called SNAPS and IBOBs. With sixteen 14-bit ADCs, two 100 G outputs, a larger FPGA, and more up to date technology, the RFSoC Digitizer Module is vast improvement upon the previous hardware.

## 2 CAD Design and Drawings

This section includes a description of the RFSoC Digitizer Module's CAD design. An image of the CAD model is shown in Figure 1 and 2. One can see the internal arrangement of the HTG-ZRF16 board (middle rear), power supply (front right), and directional fans (left rear and front right). The lid of the enclosure, not shown in this Figure, is perforated to further increase cooling. The panel facing the viewer in Figure 1 is considered the front panel. This is important to note for future sections. The majority of the RFSoC Digitizer Module's enclosure is off the shelf (PN: 24563-174) except for a few parts: the front panel, the back panel, the base plate, and the cable clamp. These custom parts were made by Front Panel Express, and the drawings can be found in Appendix A.

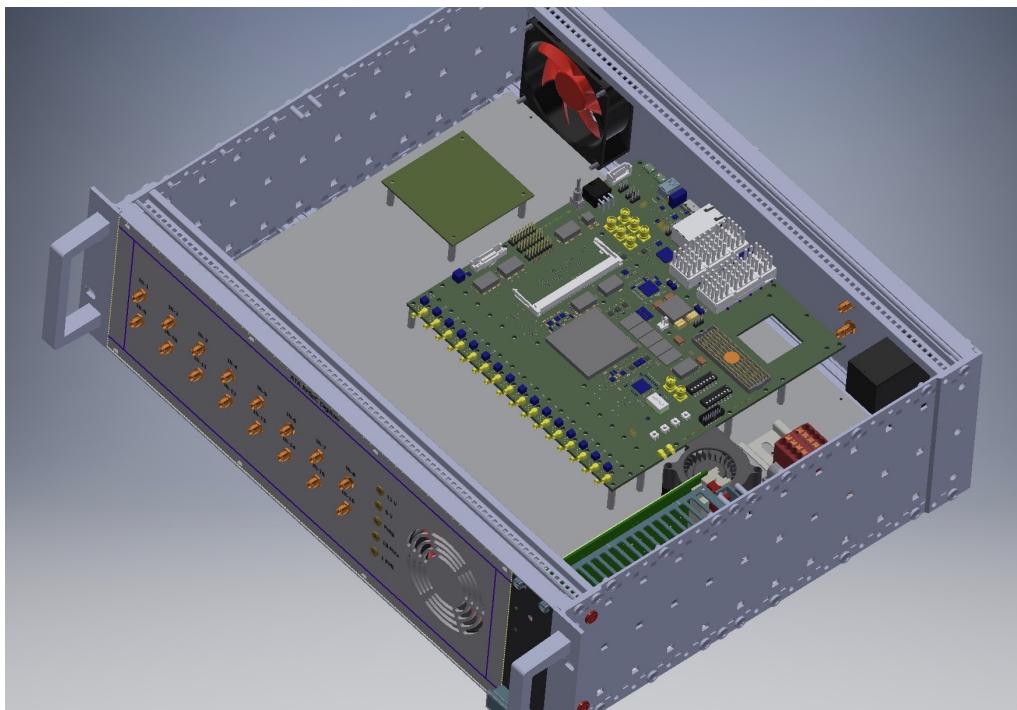


Figure 1: ISO view of the RFSoC CAD

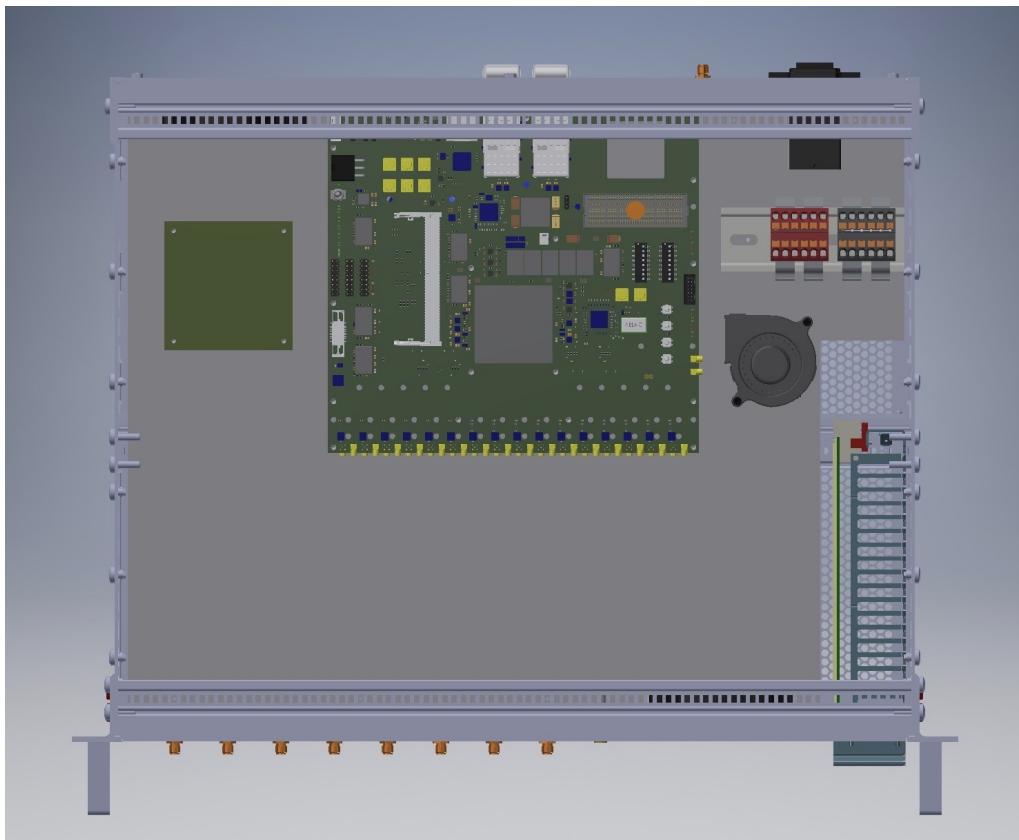


Figure 2: Top View of the RFSoC CAD

For a part list of the RFSoC Digitizer Module, except for the HTG-ZRF16 board and the Interface Board, see Appendix B.

### 3 HTG-ZRF16 Board

The HTG-ZRF16 board, seen in Figure 3, is a product of HiTech Global. It is populated with a Xilinx ZYNQ UltraScale+ RFSoC ZU49DR FPGA. There are two on-board 100Gbps QSFP28 connectors allowing high-speed data processing via an optical interface. The board also has sixteen 14-bit ADCs with a sampling rate of 2.5 GSPS.

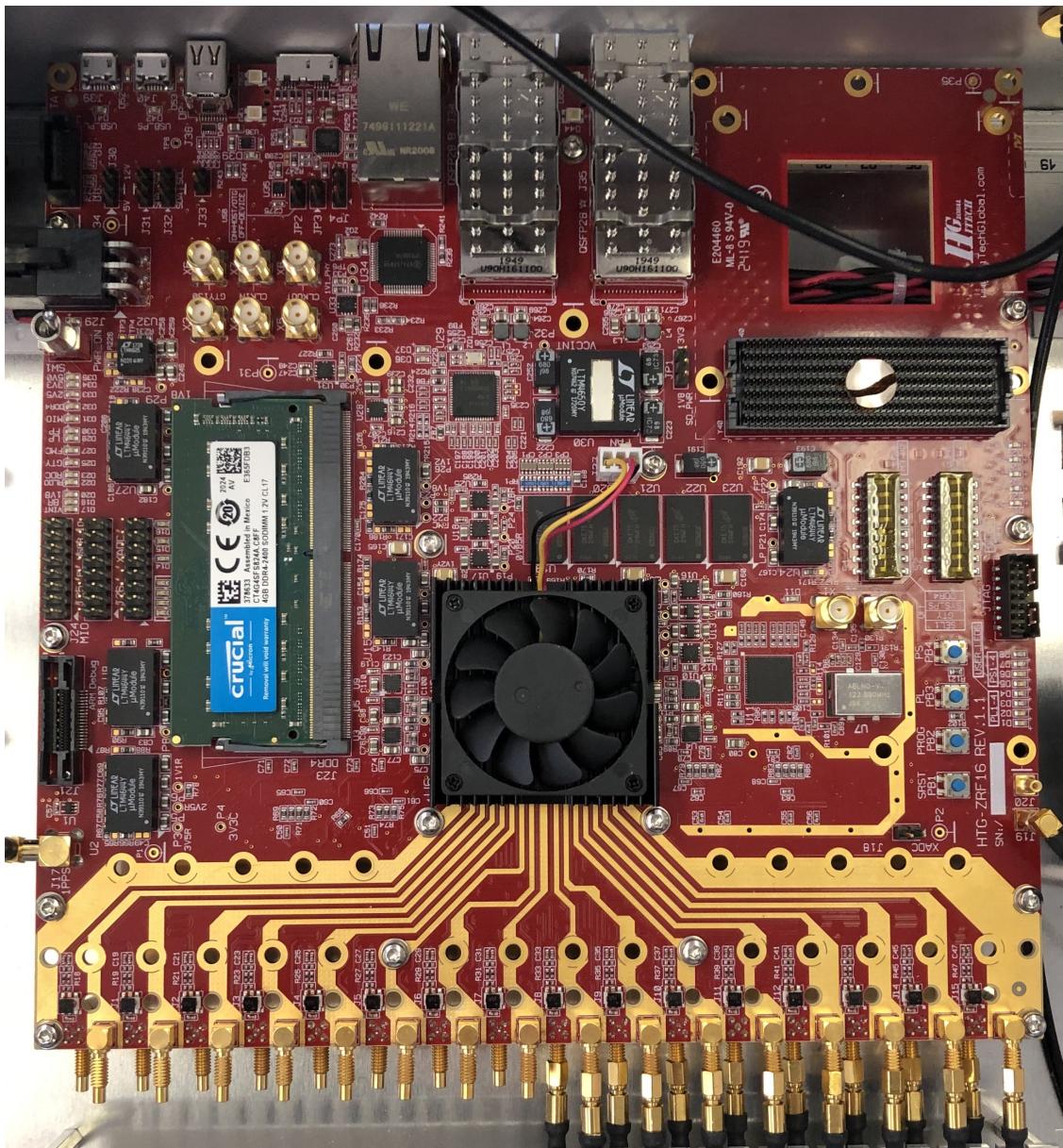


Figure 3: The HTG-ZRF16 Board Produced by HiTech Global

At the ATA, the RFSoC Digitizer Modules are operated at a sample rate of 2.048 GSPS. This is because the IF bandwidth is 700 MHz and centered at 512 MHz thus giving the system a 162 MHz leeway to prevent aliasing. Note that due to a known flaw, the HTG-ZRF16 boards purchased for the ATA were retrofitted by HiTech Global (Figure 4). Specifically, pin 44 (OSCin) of the LMK PLL chip was *not* AC-coupled to ground as it should have been and was instead connected directly to ground. Hence, HiTech Global installed a capacitor in between pin 44 of the LMK PLL chip and ground as a retrofit for this issue.

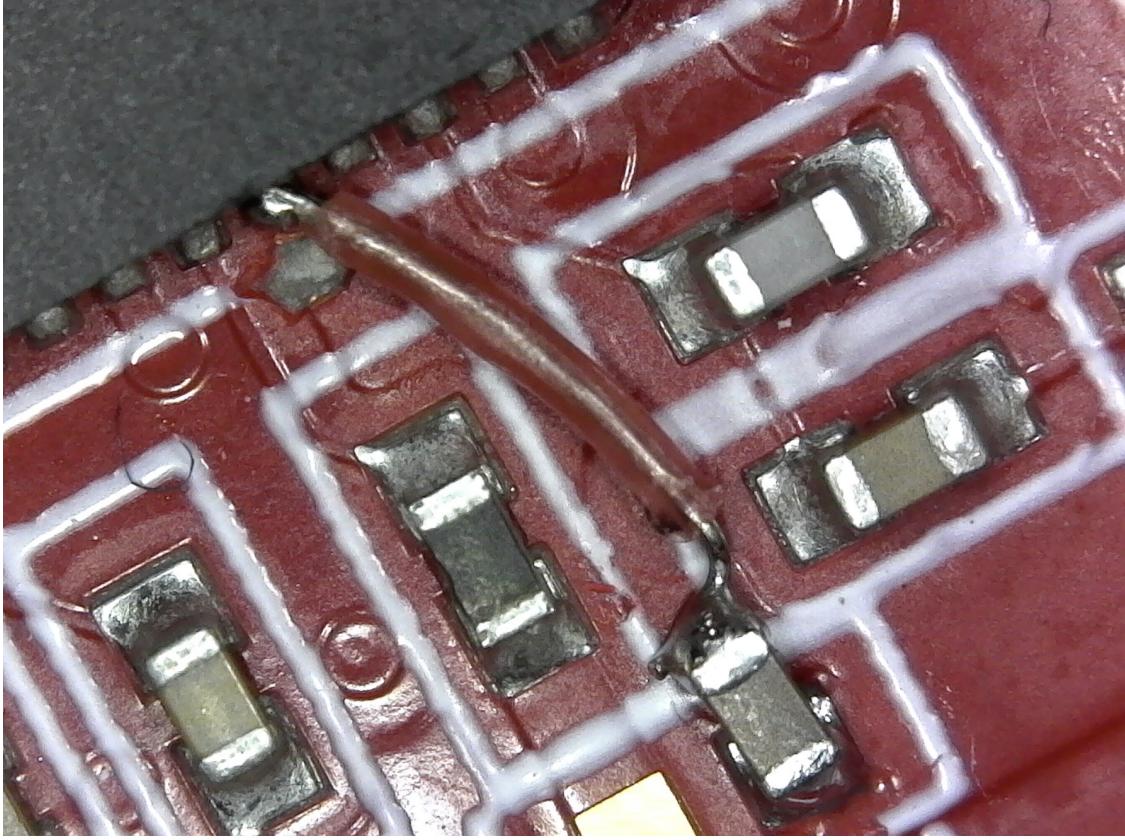


Figure 4: The HTG-ZRF16 Board with Capacitor Retrofit on Pin 44 of the LMK PLL Chip

### 3.1 Heat Sink Fan

While in use, the FPGA can reach high temperatures. Hence, the HTG-ZRF16 board comes with a heat sink fan mounted onto the FPGA (Figure 5). However, during initial use of the first RFSoC Digitizer Module, the temperature of the FPGA reached  $90 - 95^{\circ}\text{C}$  which is uncomfortably close to the FPGA's maximum temperature of  $100^{\circ}\text{C}$ . It was, therefore, determined that the original heat sink fan was insufficient at keeping the FPGA's temperature within acceptable levels and so was removed (Figure 6).

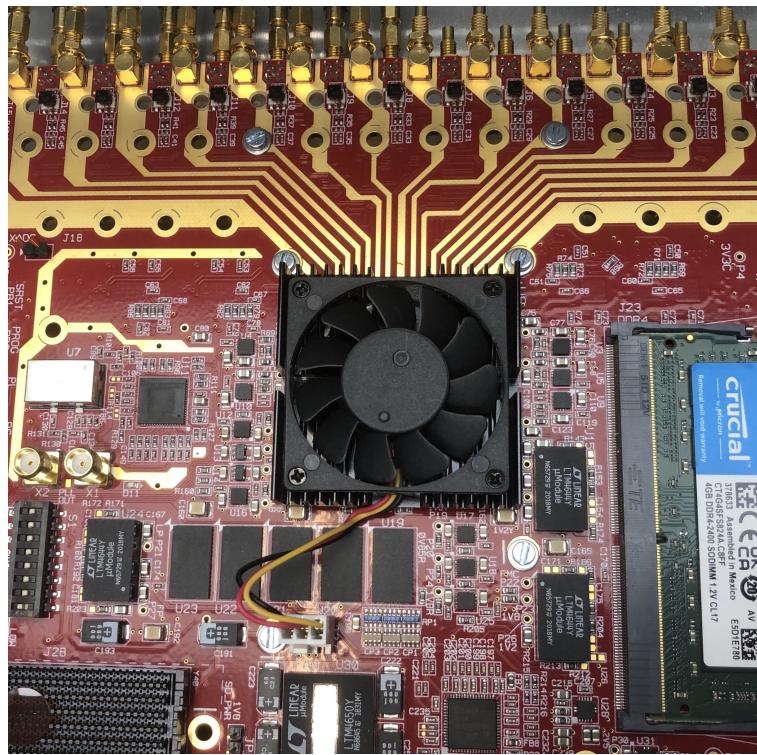


Figure 5: HTG-ZRF16 Board with the HiTech Global Heat Sink Fan

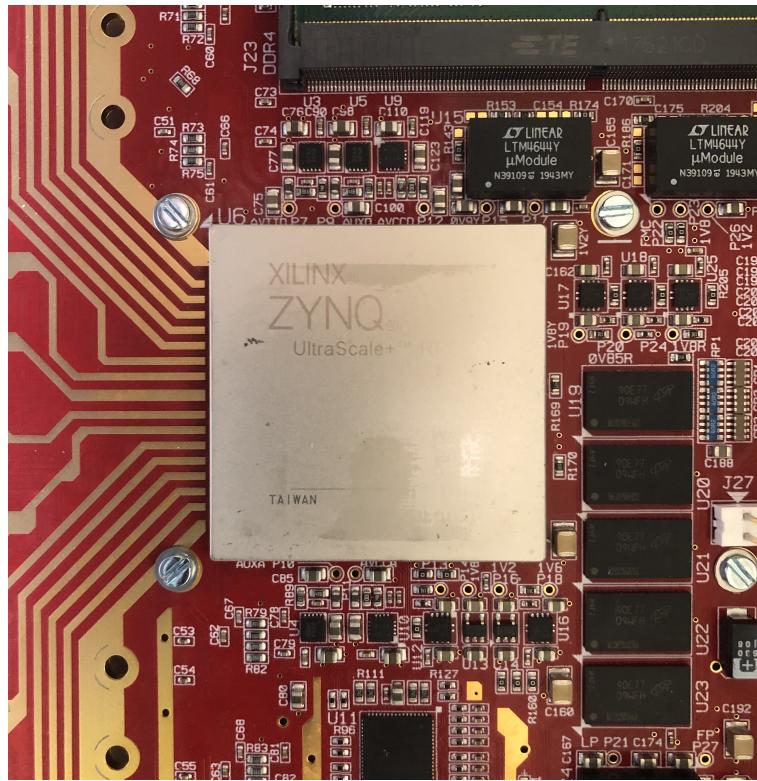


Figure 6: The HTG-ZRF16 Board's FPGA with the HiTech Global Heat Sink Fan Removed

In place of the HiTech Global heat sink fan, a new heat sink (PN: ATS-55450W-C1-R0) and fan (PN: AFB04512HA) were installed (Figure 7). This pairing was able to reduce the temperature to  $60 - 65^{\circ}\text{C}$  which was deemed acceptable.

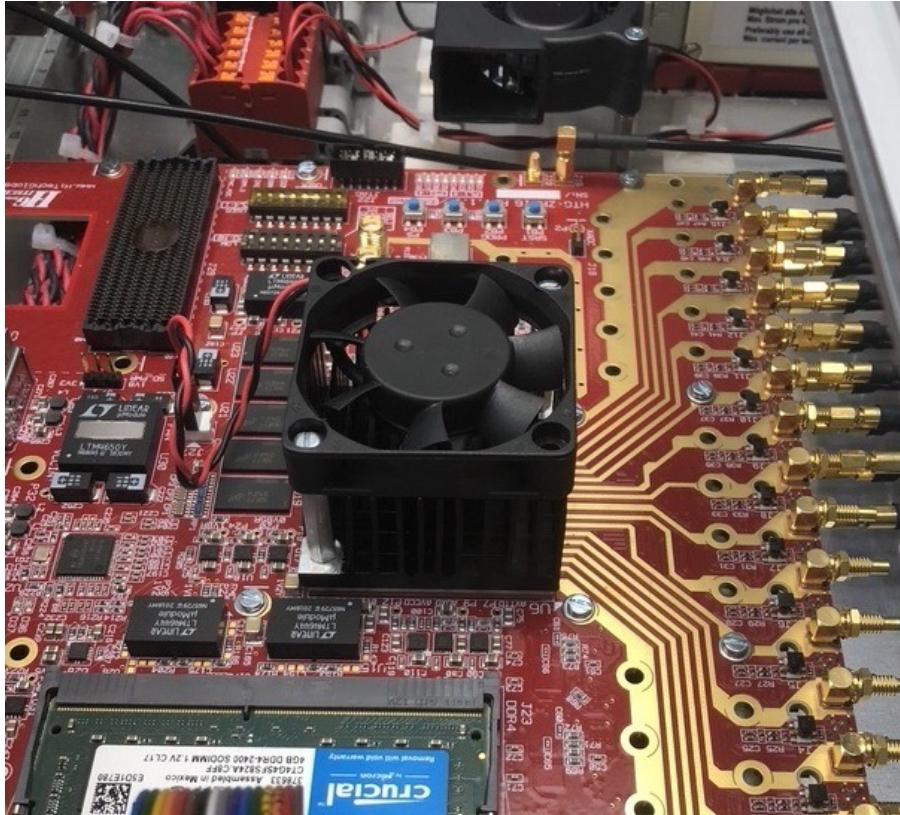


Figure 7: The HTG-ZRF16 Board with the New Heat Sink and Fan Installed

## 4 Interface Board

The Interface Board is designed as junction between to the HTG-ZRF16 board and the front panel LEDs which indicate the functionality status of the HTG-ZRF16 board. Assembled in house, Figure 8 shows how a completed Interface Board should look. A list of all its required parts appears in Appendix C.

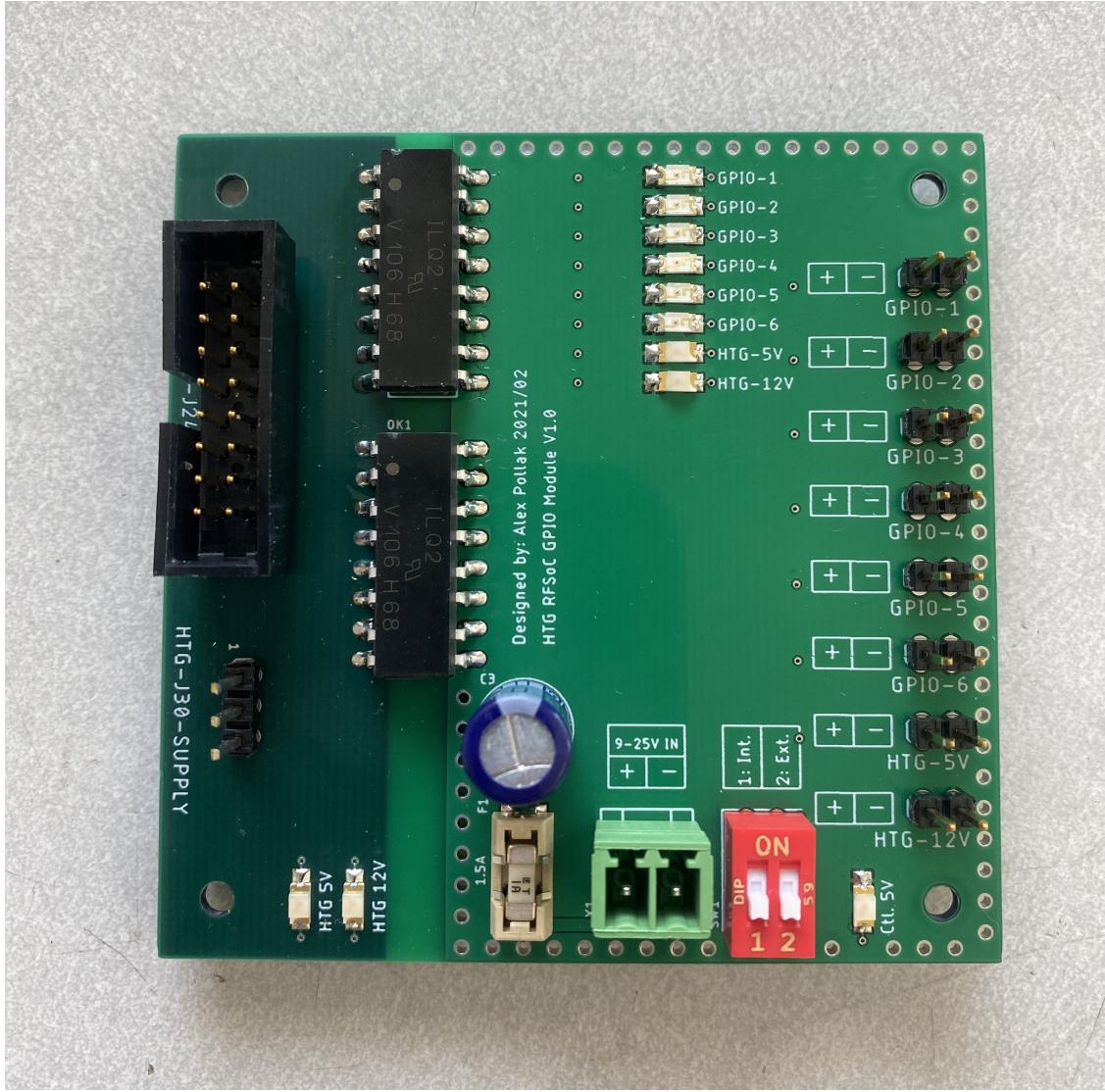


Figure 8: Completed Interface Board

## 4.1 Design

The Interface Board electrically isolates any signals from the HTG-ZRF16 board via optocouplers (OK1 and OK2) to avoid any noise contamination. The board is designed to accept 9-25V DC as an input and includes several yellow LEDs (HTG-5V, HTG-12V, HTG 5V, HTG 12V, and Ctl. 5V) that indicate the supply voltage of the HTG-ZRF16 board and Interface Board. Additionally, there are green LEDs (GPIO-1 through GPIO-6) for the HTG-ZRF16 board's GPIOs. Currently, only GPIO 1-3 are used and are set to indicate the HTG-ZRF16 board programming status, the 10 MHz signal, and the 1 PPS signal. Both the green and yellow LEDs are duplicated on the front panel of the module and are connected to the Interface Board via pin-headers. All of these functionalities are reflected in the schematic, Appendix D, and layout, Figure 9, of the Interface Board. The Interface Board voltage range is 9-25V.

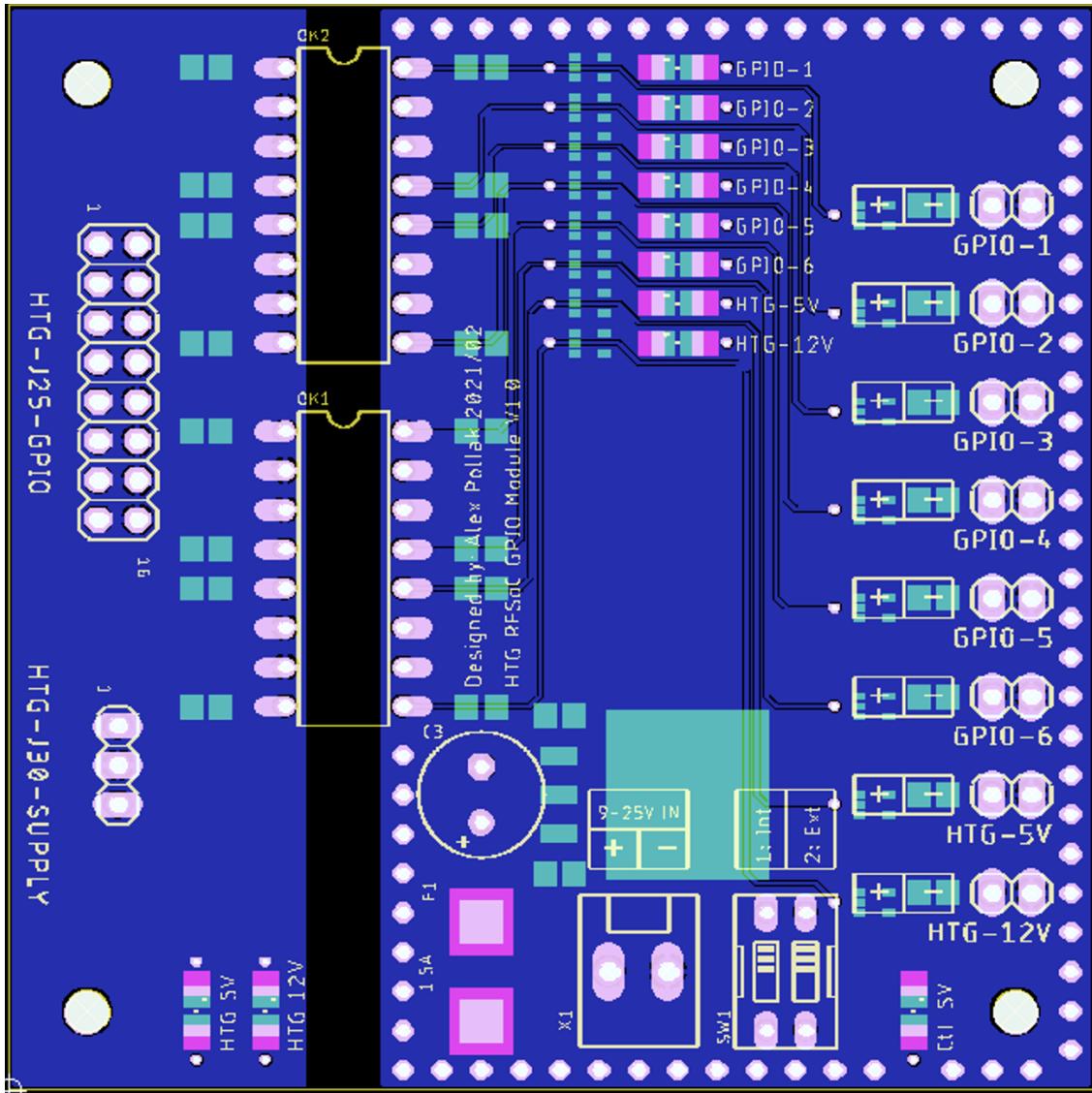


Figure 9: Interface Board Layout

## 5 Power Supply

The module's HTG-ZRF16 board, cooling fans, and the Interface Board are powered with a Schroff Max 180 (PN: 13100-151). The unit is mounted directly to the front panel of the enclosure. The operating temperature range of the power supply is from  $-25^{\circ}\text{C}$  through  $85^{\circ}\text{C}$ , and the technical specifications are shown in Table 1. The power entry module (PN: 4304.4005), mounted in the back panel, combines an IEC inlet and a mains filter with a dual-fuse holder. The AC supply fuse current rating for this unit is selected to be 2 A (PN: 0239002.HXP).

Table 1: Power Supply Specification

Description	Output Voltage	Output Current	Power W	Input Voltage
MAX180-112	12 VDC	13A	156W	100 ~ 240 VAC

## 6 Enclosure Wiring

This section outlines the internal connections of the RFSoC Digitizer Module. It is broken up into how parts connect to the front panel, the Interface Board, the HTG-ZRF16 board, the power supply, and the power entry module. Note that there are parts required for wiring the module that do not appear on part lists. This is because they are considered on-hand supplies. These parts include shrink tube, solder, hook up wire, and common terminals.

### 6.1 Front & Back Panel

This section includes the locations of where cables enter the module and connect to the HTG-ZRF16 board within.

Table 2: Cable Connections for Front Panel

Panel Label	Board Connector Number	Type of Board Connector
IN-1	J9	SSMC
IN-2	J10	SSMC
IN-3	J11	SSMC
IN-4	J12	SSMC
IN-5	J13	SSMC
IN-6	J14	SSMC
IN-7	J15	SSMC
IN-8	J16	SSMC
IN-9	J51	SSMC
IN-10	J52	SSMC
IN-11	J53	SSMC
IN-12	J54	SSMC
IN-13	J55	SSMC
IN-14	J56	SSMC
IN-15	J57	SSMC
IN-16	J58	SSMC

Table 3: Cable Connections for Back Panel

Panel Label	Board Connector Number	Type of Board Connector
1 PPS	J17	MCX
10 MHz	J19	SSMC
100 GbE P0	J35	QSFP28
100 GbE P1	J34	QSFP28
1 GbE	J37	RJ45

## 6.2 Interface Board

The Interface Board is connected to the power supply (PN: 13100-151 ), the HTG-ZRF16 board, and the LEDs (PN: Q6F7BXXB02E).

For the power supply connection, a twisted pair of red and black 18 awg wire was made. Then two E7508 gray ferrules were crimped onto one end and inserted into a 2 Way Cable Mount Screw Terminal (PN: 1803578). This then plugs into the straight PCB terminal block header (PN: 1803426) labeled X1 on the Interface Board.

The HTG-ZRF16 board is connected to the Interface Board via a a 16 to 16 GPIO Ribbon Cable (PN:IDSD-08-D-06.00) and a twisted triplet of yellow, black, and orange 24 awg wire. The GPIO Ribbon Cable provides the status of GPIO's 1-3 to the green LEDs while the twisted triplet provides the status of power to the HTG-ZRF16 board (HTG 5V and 12V) to the yellow LEDs. The GPIO Ribbon Cable plugs into HTG-J25-GPIO on the Interface Board and J25 on the HTG-ZRF16 board. The twisted triplet was crimped with M20 Crimp Terminals (PN:M20-1180042) which were then inserted into a 3 Pin SIL Housing (PN: M20-1060300). The twisted triplet plugs into HTG-J30-Supply on the Interface Board and J30 on the HTG-ZRF16 board. See Figure 10 for how the triple if orientated on each board.



Figure 10: HTG-ZRF16 and Interface Board's Cable Orientations

The five LEDs' wires are extended with red and black 28 awg as to reach the Interface Board. They are then crimped with M20 Crimp Terminals which are inserted into a 2 Pin SIL Housing (PN: M20-1060200). The Interface Board has eight two pin Straight PCB Headers (PN: 42375-2486), five of which the LEDs plug into. Table 4 shows which LEDs plug into which headers on the board.

Table 4: LED Internal Cable Connections

LED Panel Label	Board Connector Label
12V	HTG-12V
5V	HTG-5V
Prog.	GPIO-1
10 MHz	GPIO-2
1 PPS	GPIO-3

### 6.3 HTG-ZRF16 Board

The HTG-ZRF16 board connects to the power supply (PN: 13100-151), Interface Board, the heat sink fan (PN: AFB04512HA), front panel, and back panel.

The power supply is connected to the HTG-ZRF16 board via six wires, three red for 12V and three black for ground. The six wires are 18 awg and are twisted into pairs. Each wire is crimped with a Minifit plus terminal (PN: 45750-1112) and then all six are plugged into a Molex Minifit Jr. 6 Socket Receptacle (PN: 45559-0002) as shown in Figure 11. Before installation, check the polarity. Figure 10 shows how the cable looks once completed and how it should be orientated.

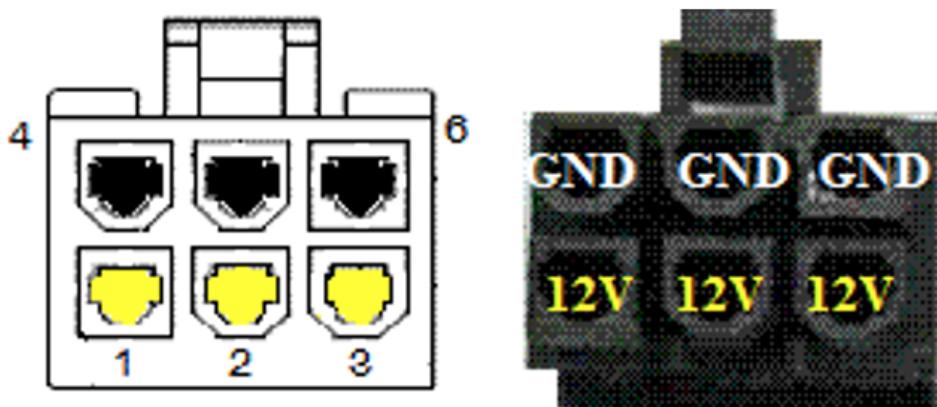


Figure 11: The Molex board power adapter

The Interface Board connections to the HTG-ZRF16 board are outlined in the Interface Board section above.

As noted in the Section 4, the HTG-ZRF16 board has a heat sink fan due to high temperature while in use. This heat sink fan is connected directly to the board for power via J27. Though, prior to being plugged in, the fan's wires are twisted together, crimped with M20 Crimp Terminals (PN:M20-1180042), and inserted into a 2 Pin SIL Housing (PN: M20-1060200).

The front and back panel connections to the HTG-ZRF16 board are outlined in Table 2 and 3. The 100 GbE P0, 100 GbE p1, and 1 GbE connections from the back panel plug directly from the back panel into the HTG-ZRF16 board. The rest of the back panel connections and all the front panel connections are done via SMA Female Bulkhead to SSMC Plug Cables (PN: PE3C4448-18),

### 6.4 The Fans

There are a total of ten fans inside the RFSoC Digitizer Module. The first of these is the heat sink fan (PN: AFB04512HA) which was already discussed in the previous section. The rest of the fans are connected to the power supply. There is the

front panel fan (PN: PF80251V1-1000U-A99), the back panel fan (PN: PF80251V1-1000U-A99), the blower fan (PN: GB1205PKV1-8AY.GN), and six base plate fans (PN: 412FM). The front panel and back panel fans wires are extended with red and black 20 awg in order to reach the power supply. The blower fan's wires are long enough as is, and the six base plate fans' wires are soldered together and extended with and red and black 20 awg wires.

Regarding how the fans should be mounted, the front panel fan should blow air into the enclosure while the back panel to sucks air out of the enclosure. The six base plate fans should be mounted such that they blow air into the enclosure. The front panel, back panel, and blower fan can all be seen in Figures 1 and 2. However, the six base plate fans are not visible, nor can they be seen in the completed enclosure (Figures 17 through 20). Figure 12 and 13, instead, shows an incomplete RFSoC Digitizer Module with the six base plate fans visible.

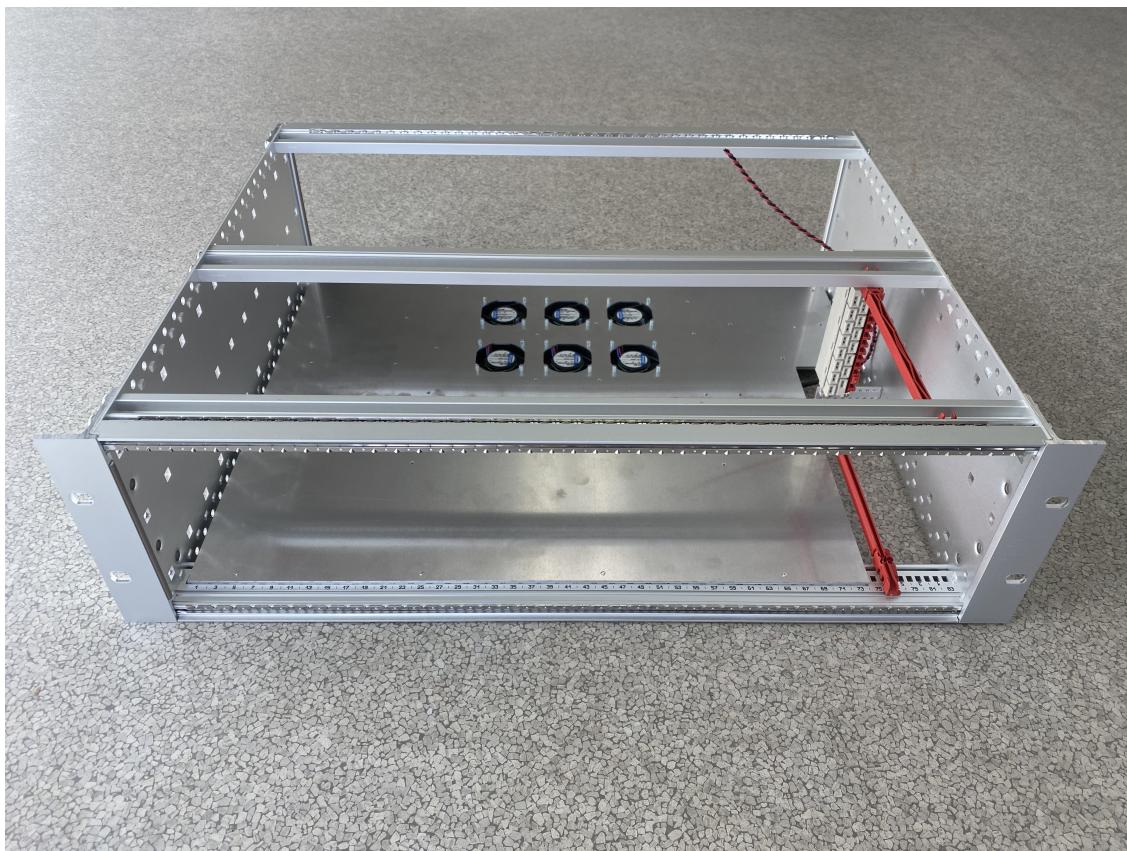


Figure 12: Front view of an incomplete RFSoC Digitizer Module

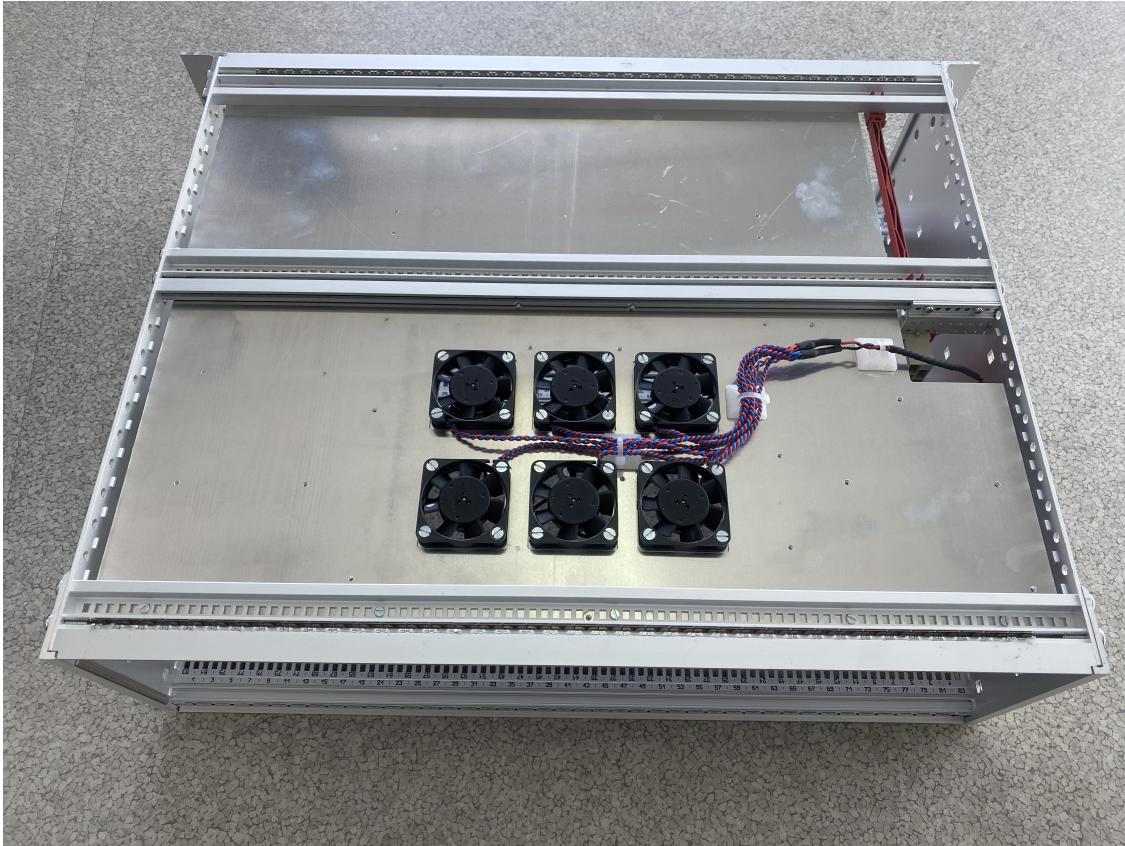


Figure 13: Back and upside down view of an incomplete RFSoC Digitizer Module

## 6.5 Power Supply

The power supply (PN: 13100-151) is connected to the Interface Board, the HTG-ZRF16 board, the fans, and the power entry module (PN: 4304.4005).

Due to the large number of components requiring power, the power supply uses a set of power distribution terminals (PN: 3273158 and 3273168) shown in Figure 14. Please see Figure 15 for a schematic that shows how the power supply is connected to the power distribution terminals. The red and black wires used are 14 awg and are both crimped with female quick disconnect terminals (PN: FDFD1-250) on the ends plugging into the power supply. The ends plugging into the power distribution terminal are just stripped. There is also a green ground wire that connects the black power distribution module to the base plate. This wire is stripped on the power distribution terminal end and crimped with a 6s eye terminal on the other. The eye terminal is screwed down to the base plate.

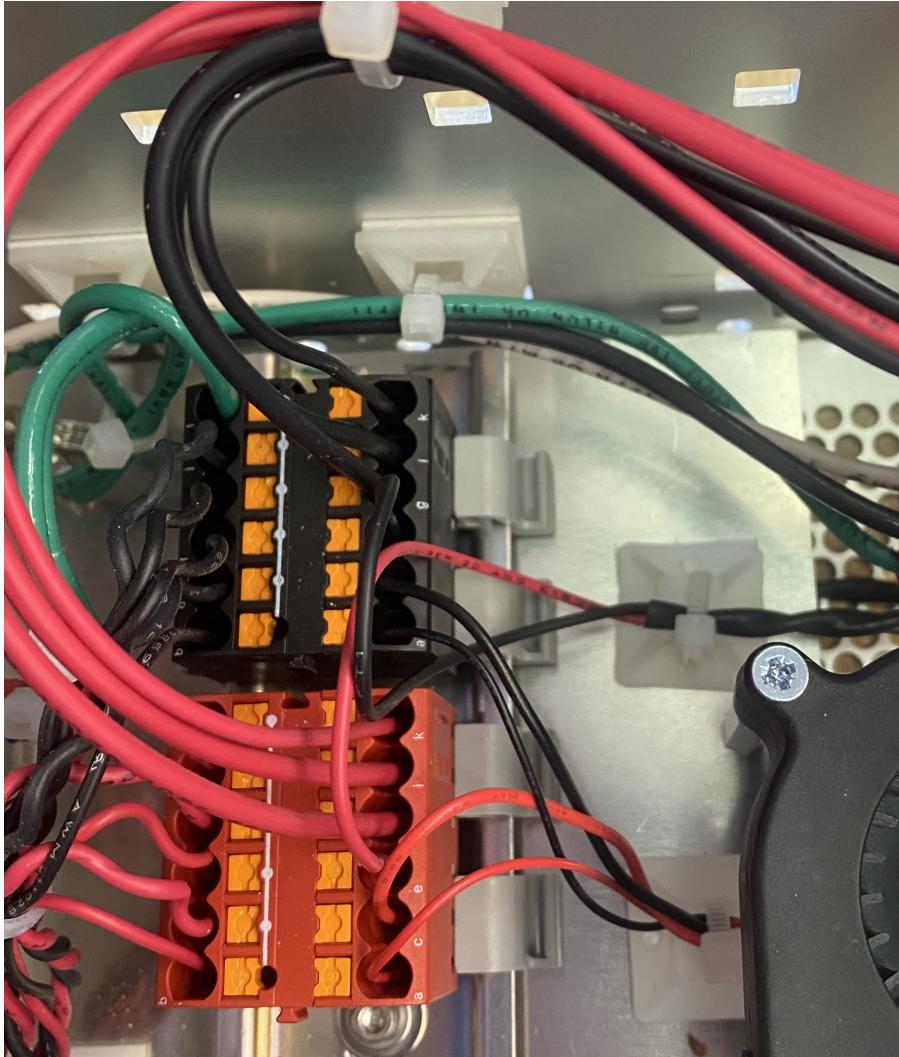


Figure 14: The Power Distribution Terminals Installed in the RFSoC Digitizer Module

A schematic of how the power distribution terminals are connected to the Interface Board, the HTG-ZRF16 board, and the fans is shown in Figure 16. See the above sections for wires gauges, terminals, and housings used for all these connections.

How the power supply is connected to the power entry module is shown in Figure 15. The black and white wires are crimped on both ends with female quick disconnect terminals. The green ground wire for the power supply has female quick disconnect terminals on both ends as well, and rather than being connected directly to the base plate, it instead plugs into the female piggyback disconnect terminal (PN: PBDD2-250) of the power entry module's ground wire.

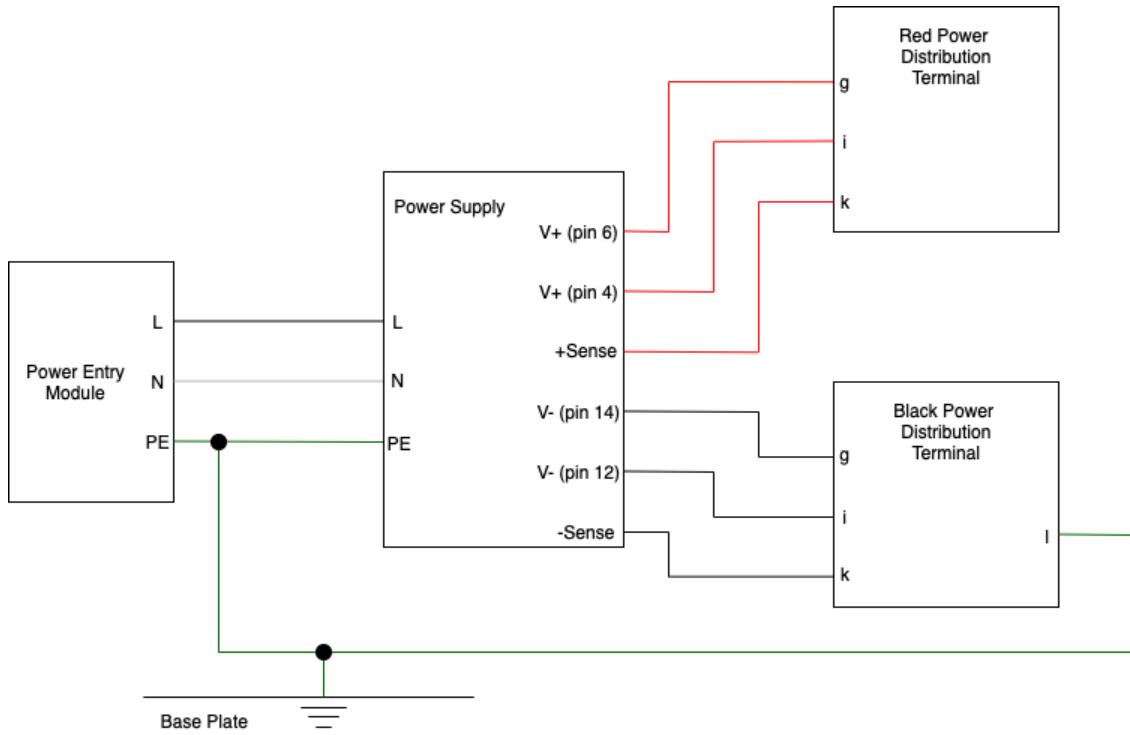


Figure 15: RFSoC Digitizer Module Power Schematic Part 1. This half of the power schematic shows the connections between the power entry module, the power supply, and the two power distribution terminals. The colors of the connections represent the color of wire used. All the wires connecting the to the power entry module and base plate are 16 awg. The rest of the wire gauges are specified in the power supply subsections.

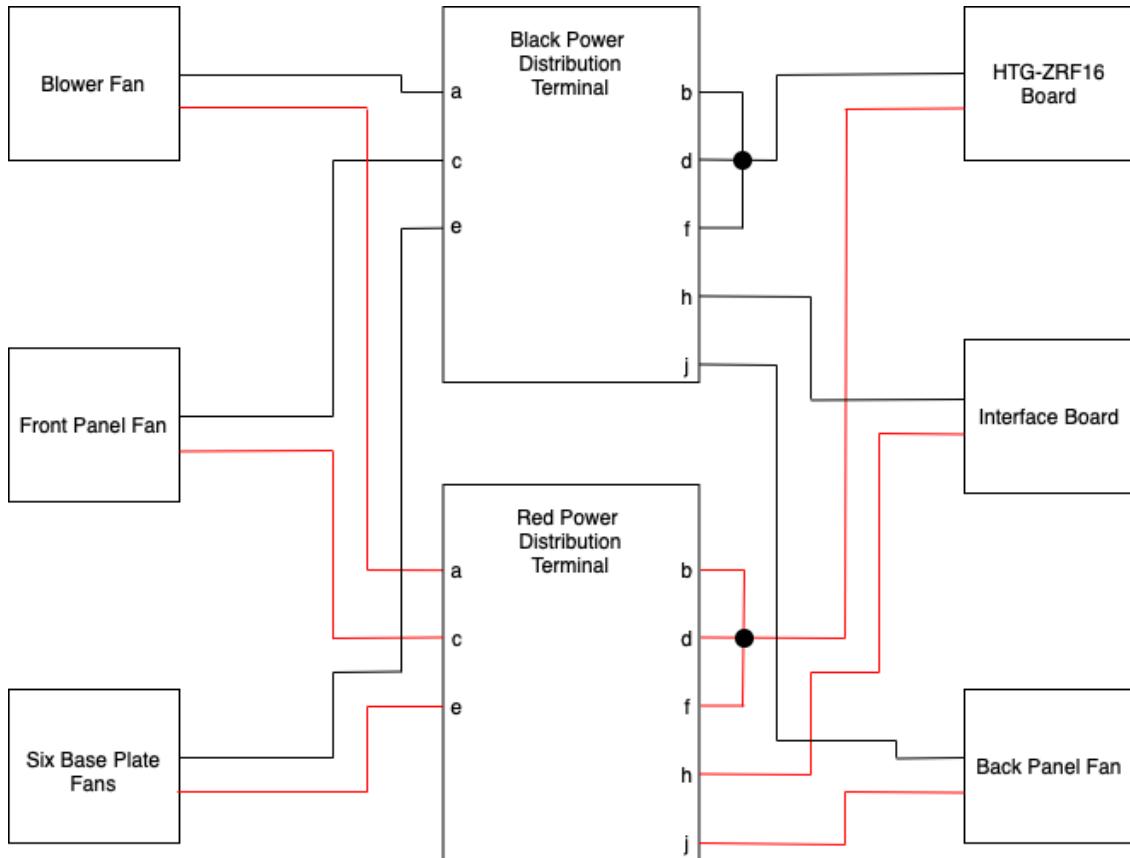


Figure 16: RFSoC Digitizer Module Power Schematic Part 2. This half of the power schematic shows the connections of the two power distribution terminals, the fans, the HTG-ZRF16 board, and the Interface Board. The colors of the connections represent the color of wire used. The wire gauges are specified in the power supply subsections.

## 6.6 The Power Entry Module

The power entry module (PN: 4304.4005) is connected to the power supply (PN: 13100-151) and the base plate. Refer to Figure 15 for the wiring schematic of the power entry module.

The power supply connection to the power entry module was already described in the previous section. The base plate is connected to the power entry module via a green 12 awg wire crimped with a 6s eye terminal on one end and a female piggyback disconnect terminal (PN: PBDD2-250) on the other. The 6s eye terminal is screwed into the base plate while the female piggyback disconnect terminal plugs into the power entry module. Note that this is the female piggyback disconnect terminal that has the green ground wire from the power supply plugging into it.

## 7 Completed Module

Upon completion, an assembled RFSoC Digitizer Module is shown in the Figures 17, 18, 19, and 20. The biggest difference between the finished enclosure and the CAD design is the wiring, screws, lids, and cable clamp (front middle between the front panel and RFSoC board in Figure 17) which were all left out in the CAD (Figures 1 and 2). Note that the new heat sink and fan had not yet been installed on the HTG-ZRF16 board in Figure 17. Furthermore, Figures 18 and 19 is missing the HTG-ZRF16 board and so, in turn, is missing the feed throughs on the front and back panels.

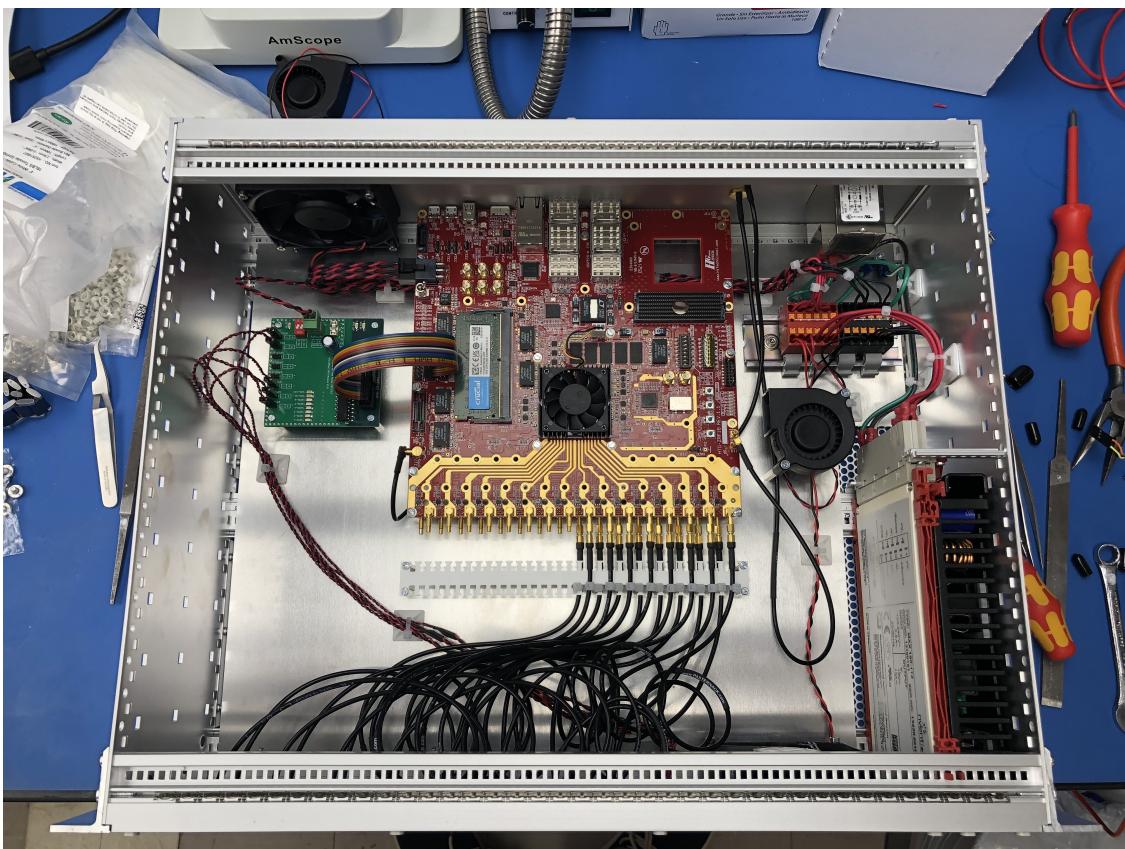


Figure 17: Completed RFSoC Digitizer Module



Figure 18: Mostly Completed RFSoC Digitizer Module from the Front

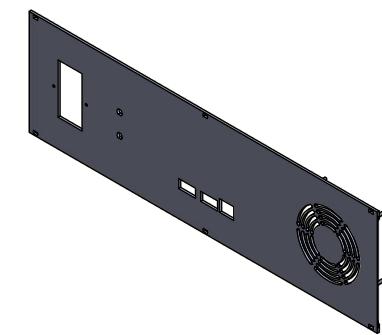
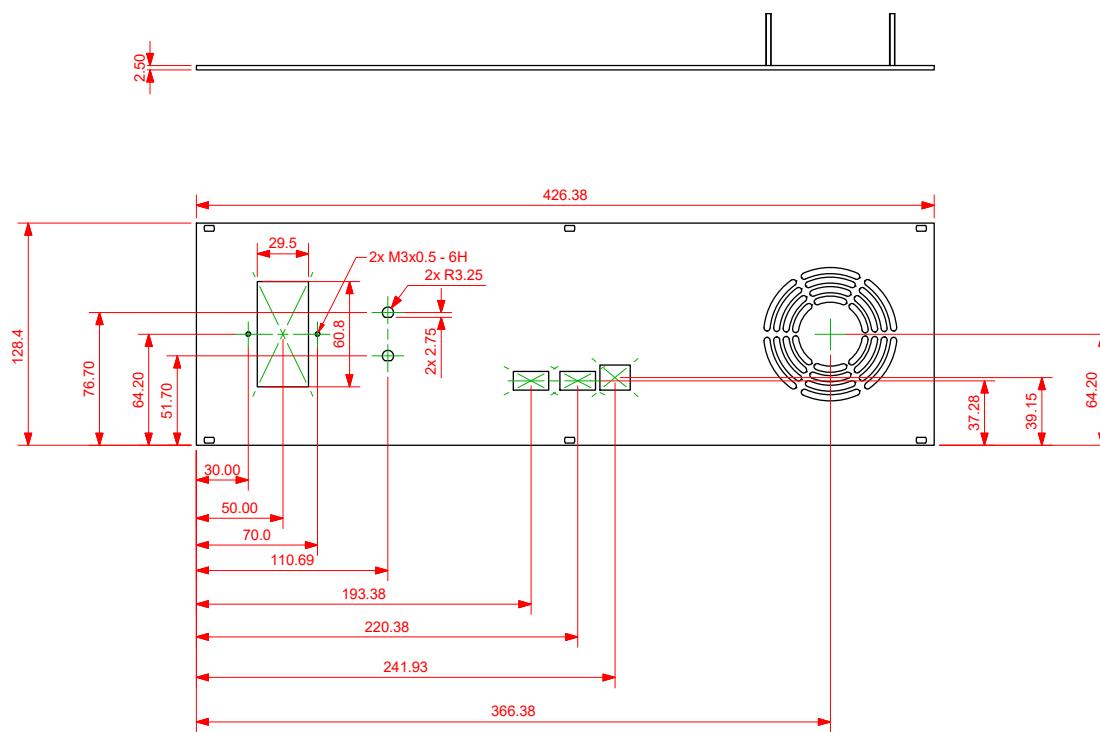


Figure 19: Mostly Completed RFSoC Digitizer Module from the Back



Figure 20: Completed RFSoC Digitizer Module Installed in Signal Processing Room. Attemplifier Modules are also pictured. The RFSoC Digitizer Modules are the first and third modules from the bottom.

# A RFSoC Enclosure Drawings

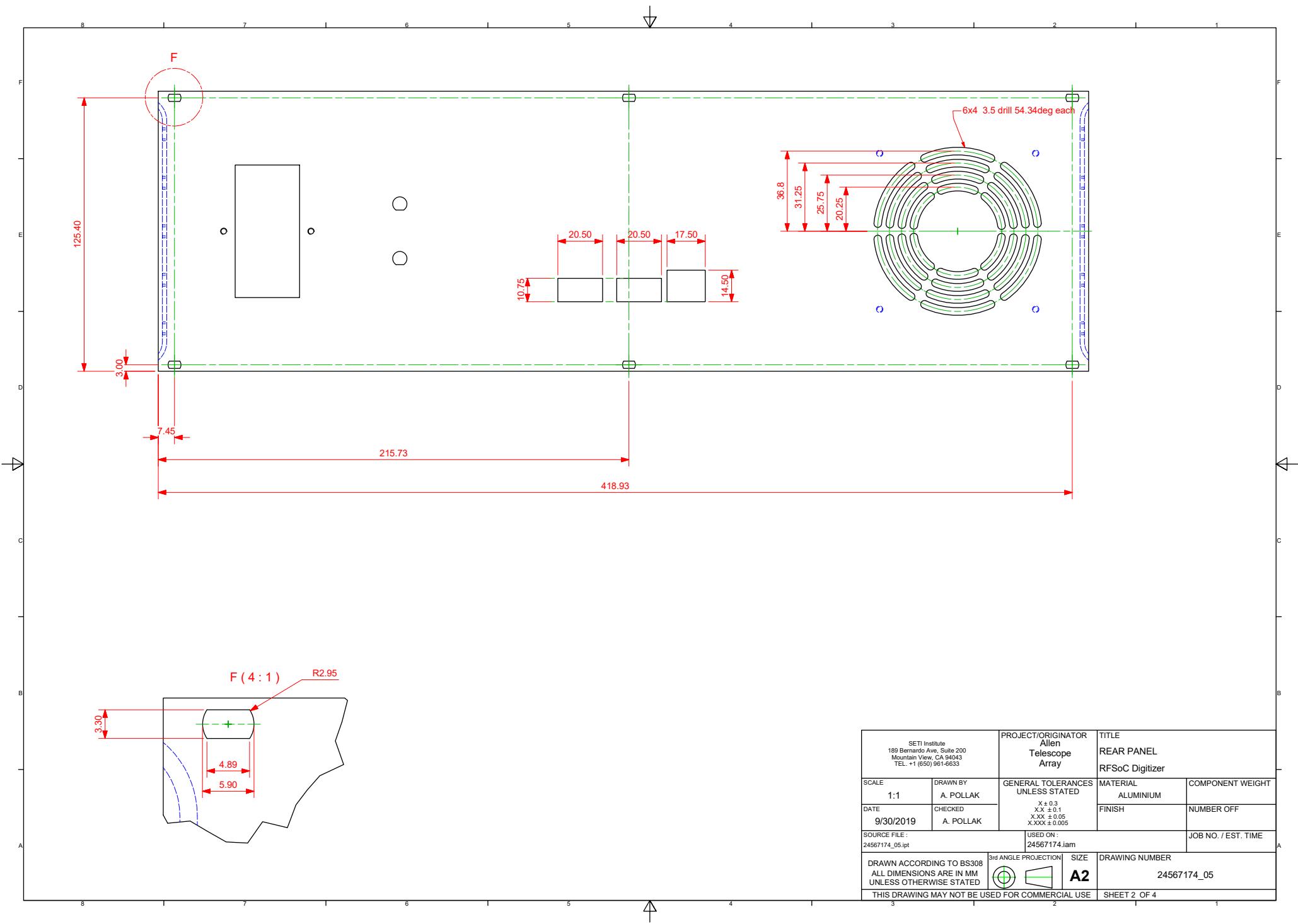


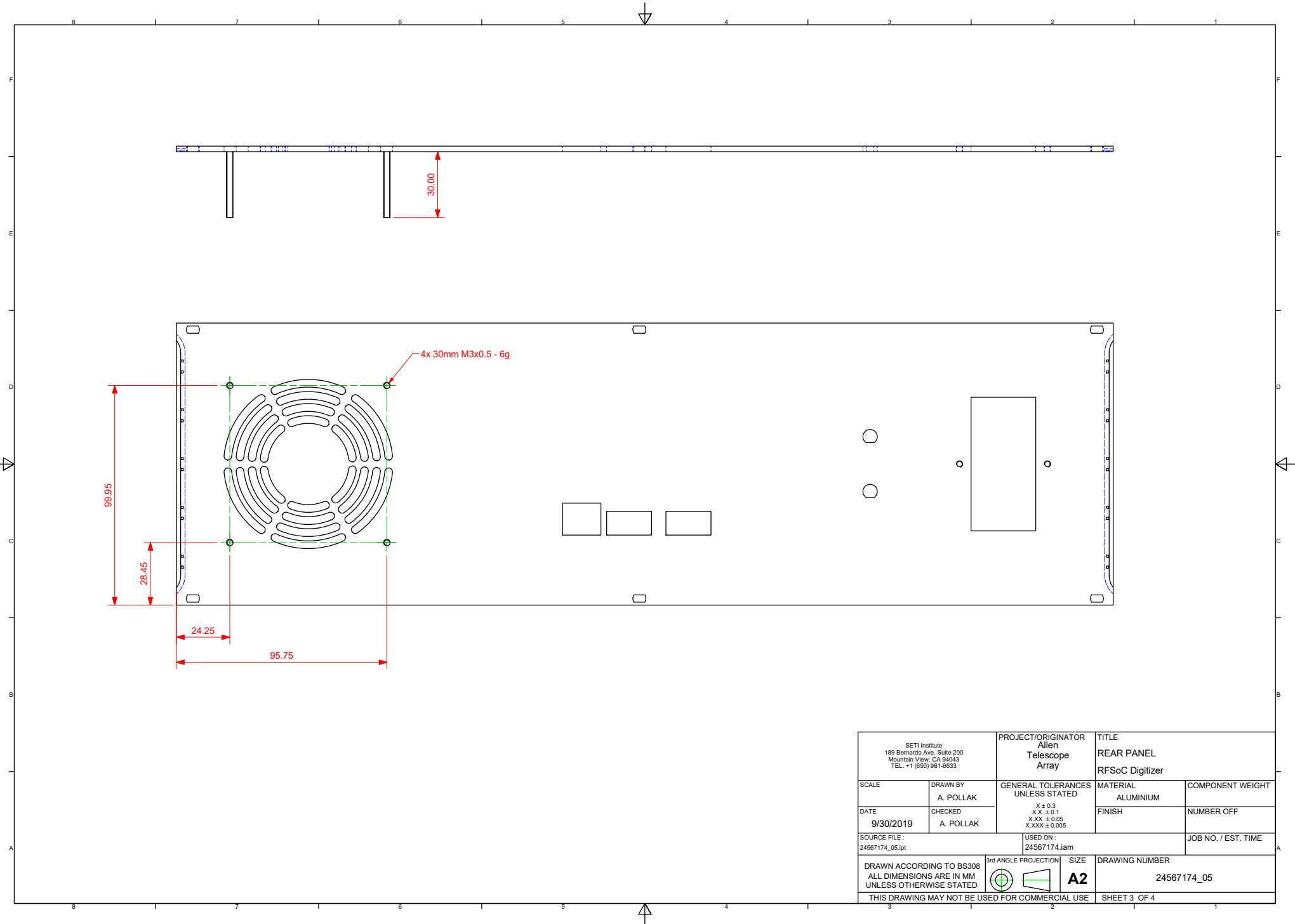
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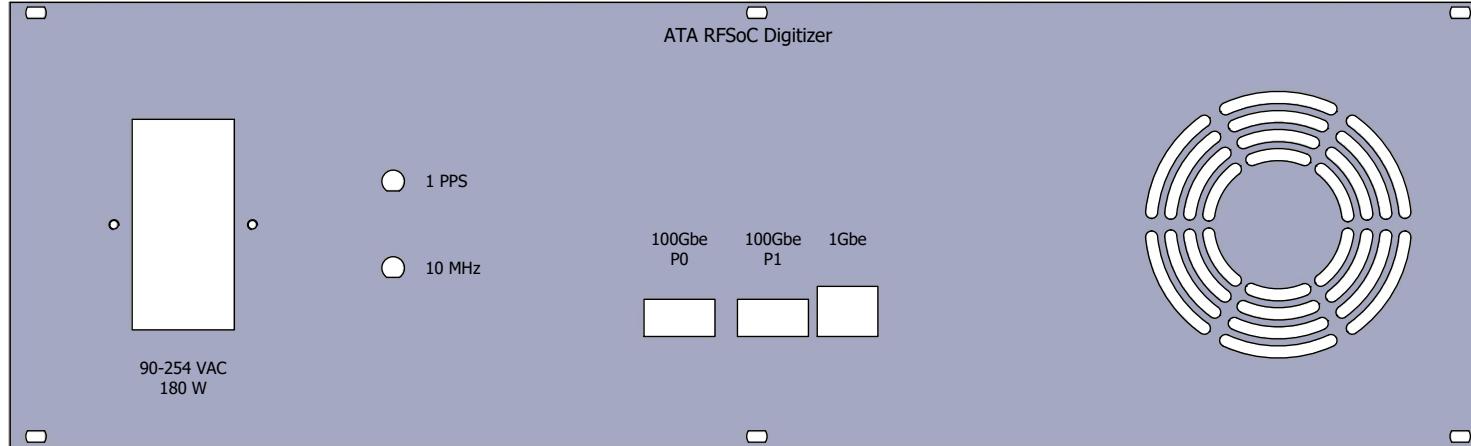
## NOTES

1. THIS SHEET SHOWS THE MODIFICATIONS FOR THE SUPPLIED REAR PANEL. (SCHROFF: 20848-097)
2. REFER TO 3D CAD GEOMETRY FOR ALL UNSPECIFIED DIMENSIONS

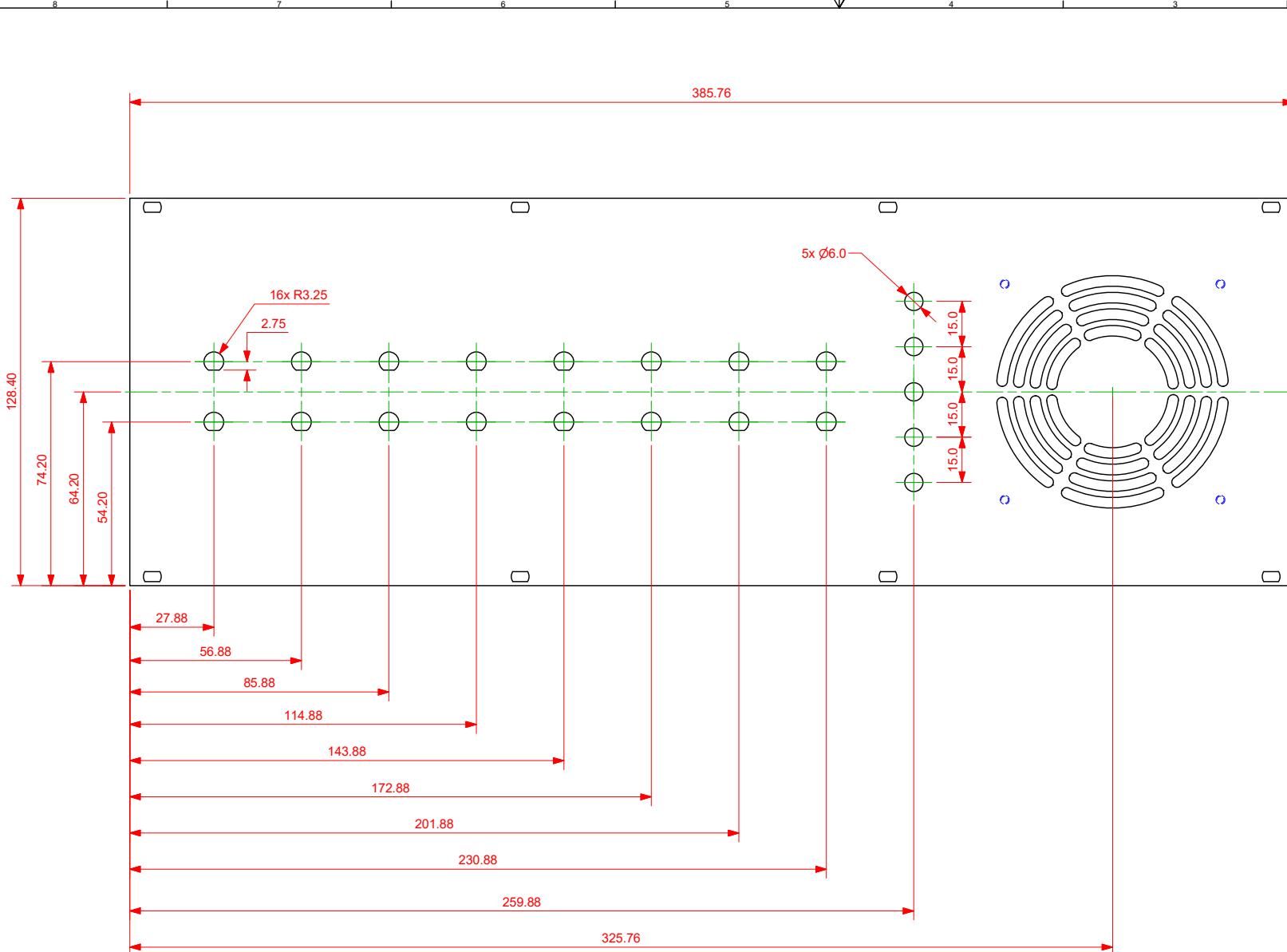
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SHEET 1 OF 4		





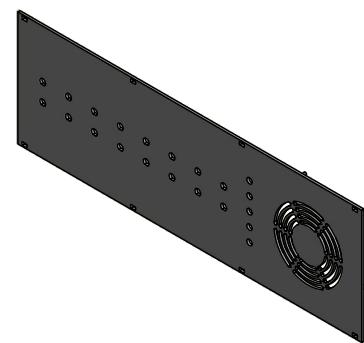


SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043 TEL: +1 (650) 961-6633		PROJECT/ORIGINATOR Allen Telescope Array	TITLE REAR PANEL RFSoC Digitizer	
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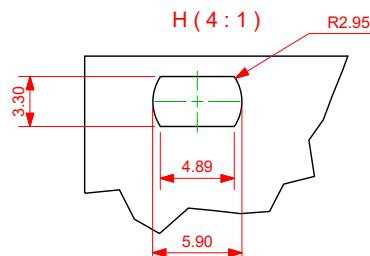
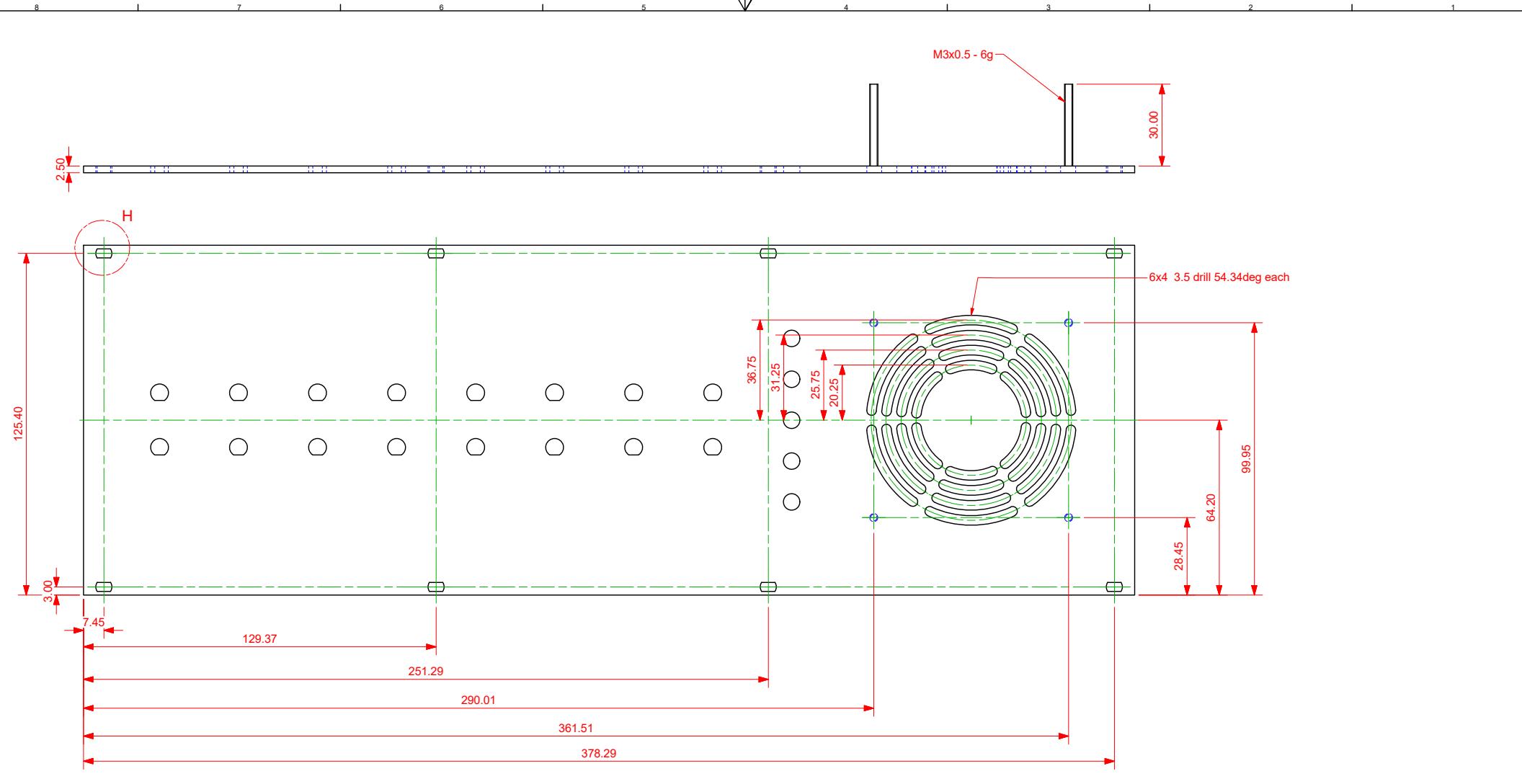
NOTES

1. THIS SHEET SHOWS THE MODIFICATIONS FOR THE SUPPLIED FRONT PANEL. (SCHROFF: 20848-097)
2. REFER TO 3D CAD GEOMETRY FOR ALL UNSPECIFIED DIMENSIONS
3. THE THIRD SHEET SHOWS THE TEXT FOR THE LASER ENGRAVING.

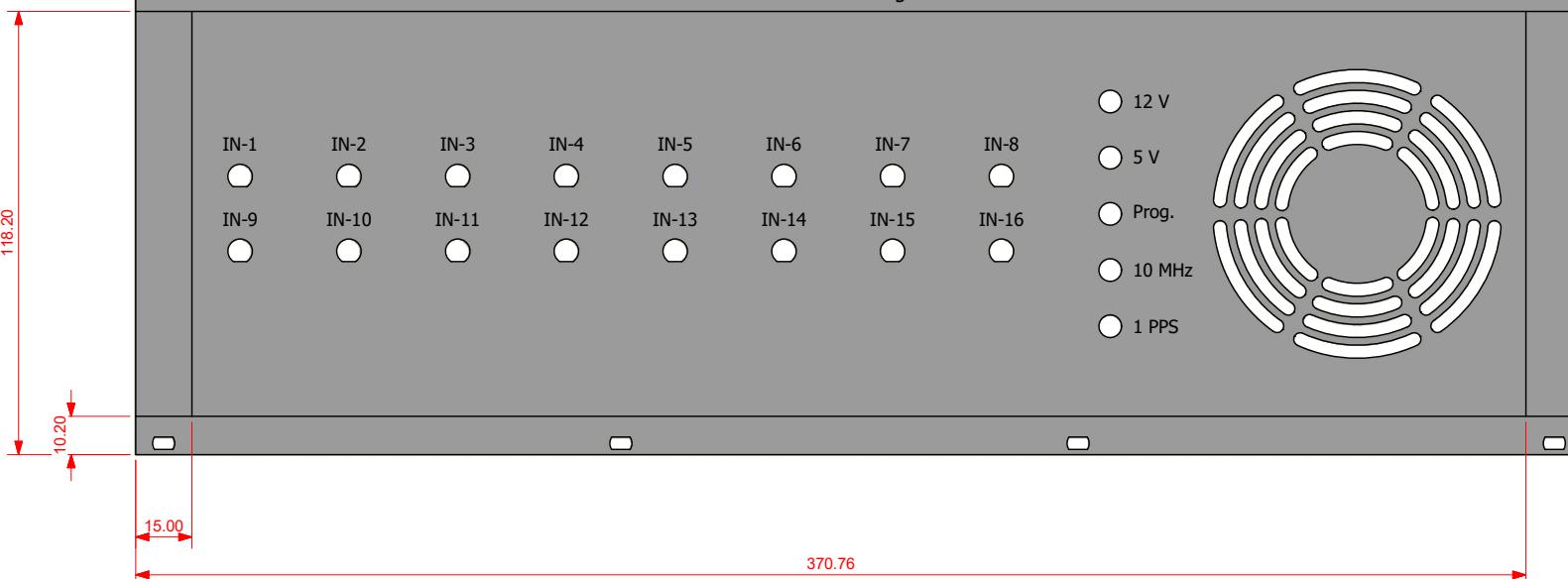


ISOMETRIC VIEW OF BASE PLATE  
(DO NOT SCALE)

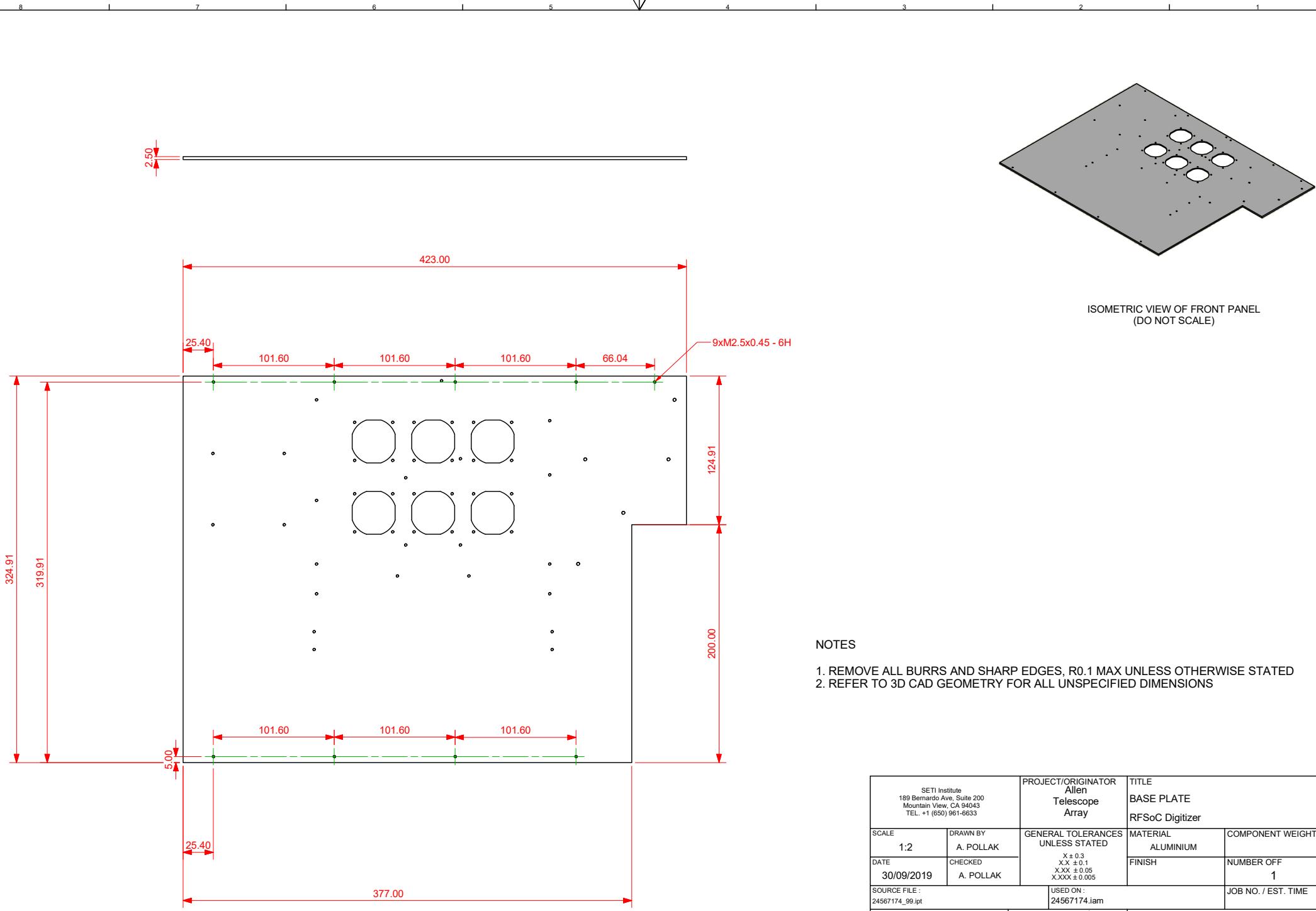
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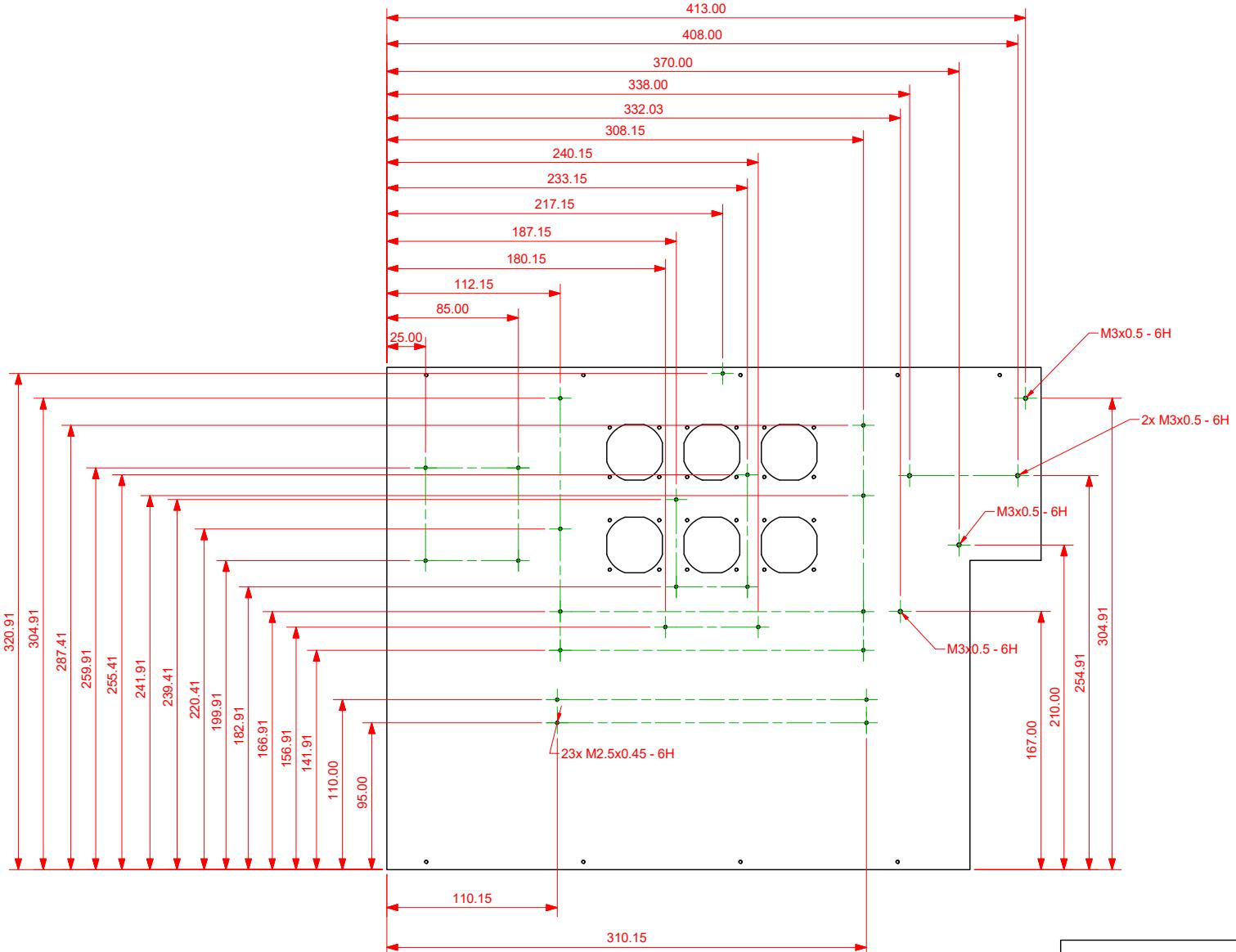
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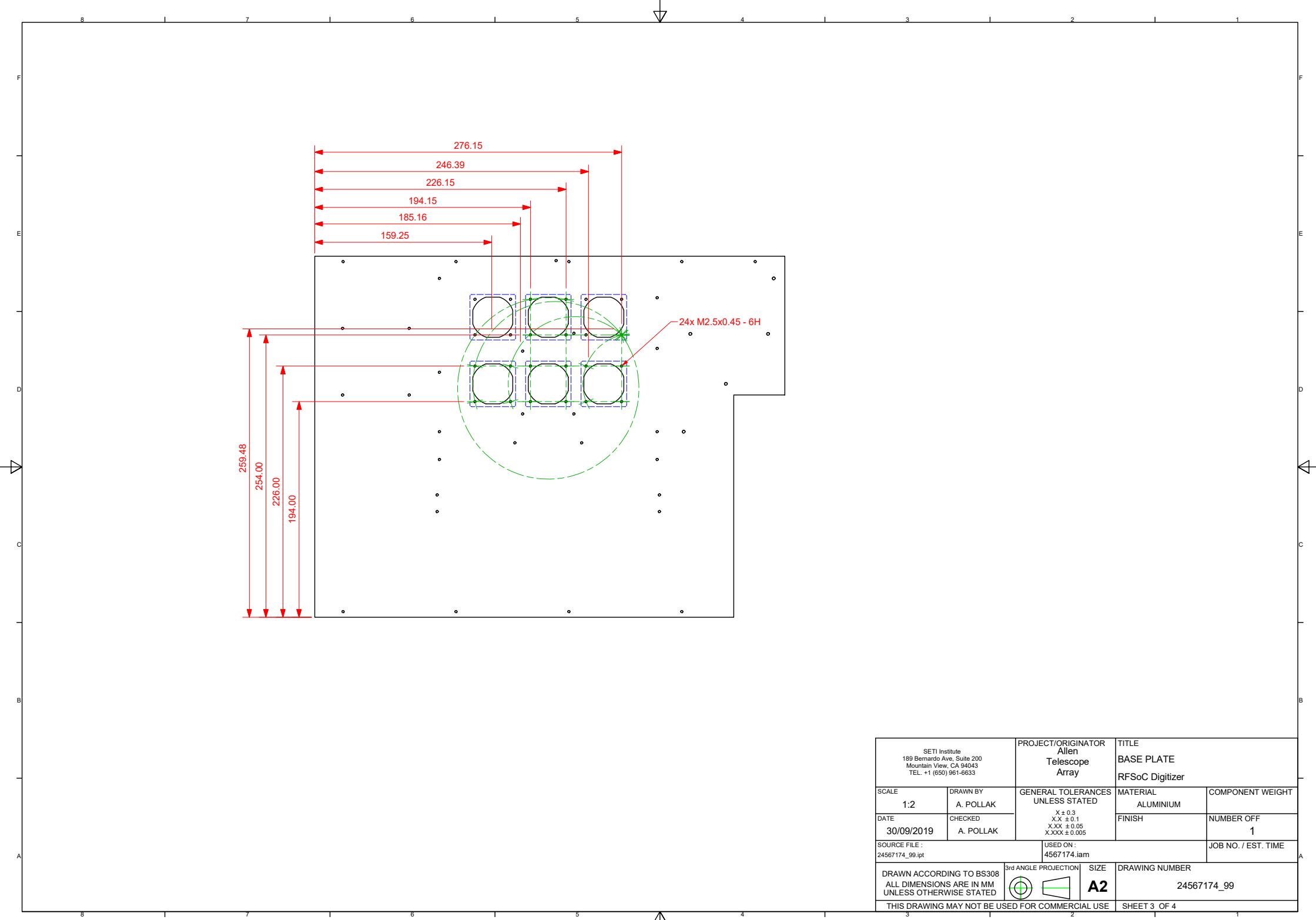
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THIS DRAWING MAY NOT BE USED FOR COMMERCIAL USE		
SHEET 3 OF 3		

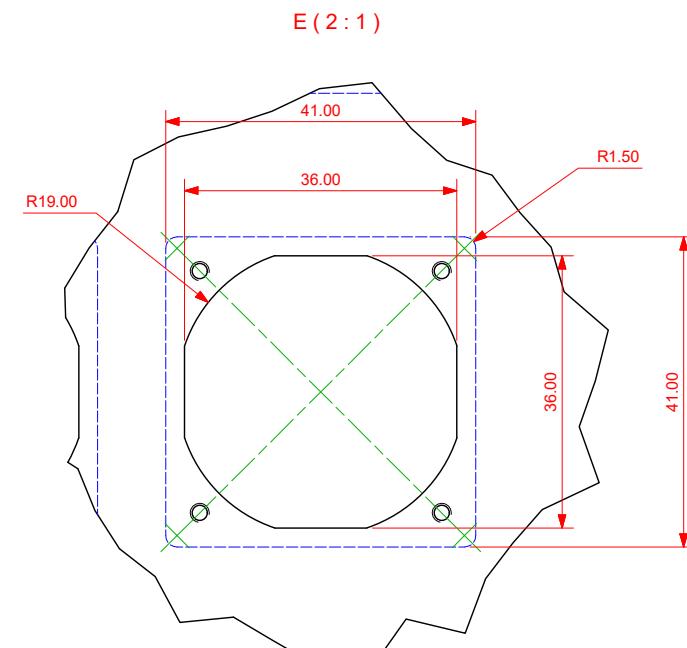
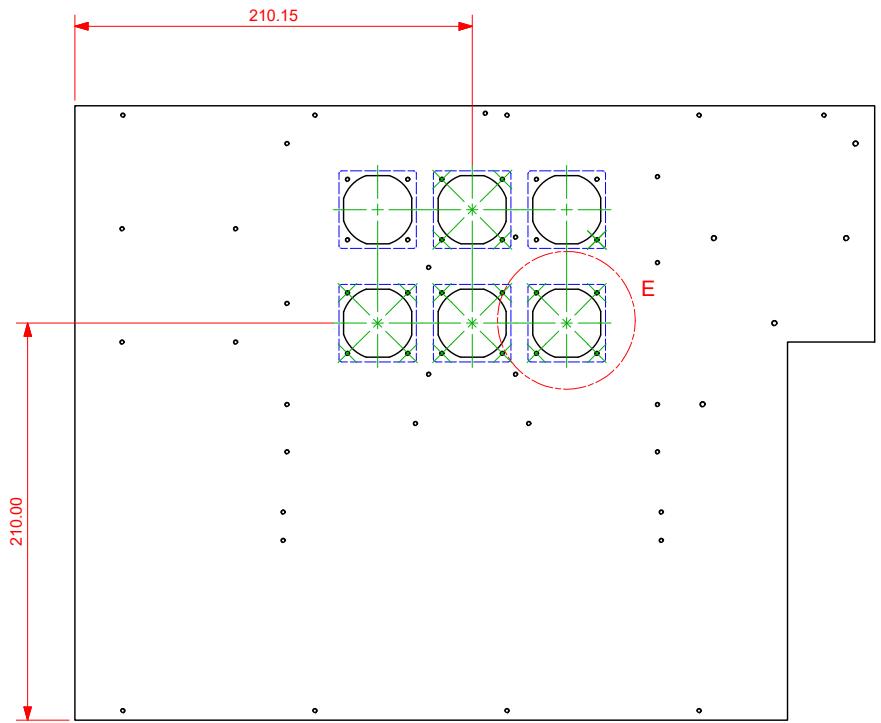


SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043 TEL. +1 (650) 961-6633	PROJECT/ORIGINATOR Allen Telescope Array	TITLE BASE PLATE RFSoC Digitizer
SCALE 1:2	DRAWN BY A. POLLAK	GENERAL TOLERANCES UNLESS STATED $X \pm 0.3$ $XX \pm 0.1$ $XXX \pm 0.05$ $XXXX \pm 0.005$
DATE 30/09/2019	CHECKED A. POLLAK	FINISH
SOURCE FILE : 24567174_99.ipt	USED ON : 24567174.ipt	NUMBER OFF 1
DRAWN ACCORDING TO BS308 ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE STATED		JOB NO. / EST. TIME
3rd ANGLE PROJECTION	SIZE A2	DRAWING NUMBER 24567174_99
THIS DRAWING MAY NOT BE USED FOR COMMERCIAL USE		
SHEET 1 OF 4		



SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043 TEL. +1 (650) 961-6633	PROJECT/ORIGINATOR Allen Telescope Array	TITLE BASE PLATE RFSoC Digitizer
SCALE 1:2	DRAWN BY A. POLLAK	GENERAL TOLERANCES UNLESS STATED $X \pm 0.3$ $XX \pm 0.1$ $XXX \pm 0.05$ $XXXX \pm 0.005$
DATE 30/09/2019	CHECKED A. POLLAK	FINISH
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THIS DRAWING MAY NOT BE USED FOR COMMERCIAL USE		
SHEET 2 OF 4		

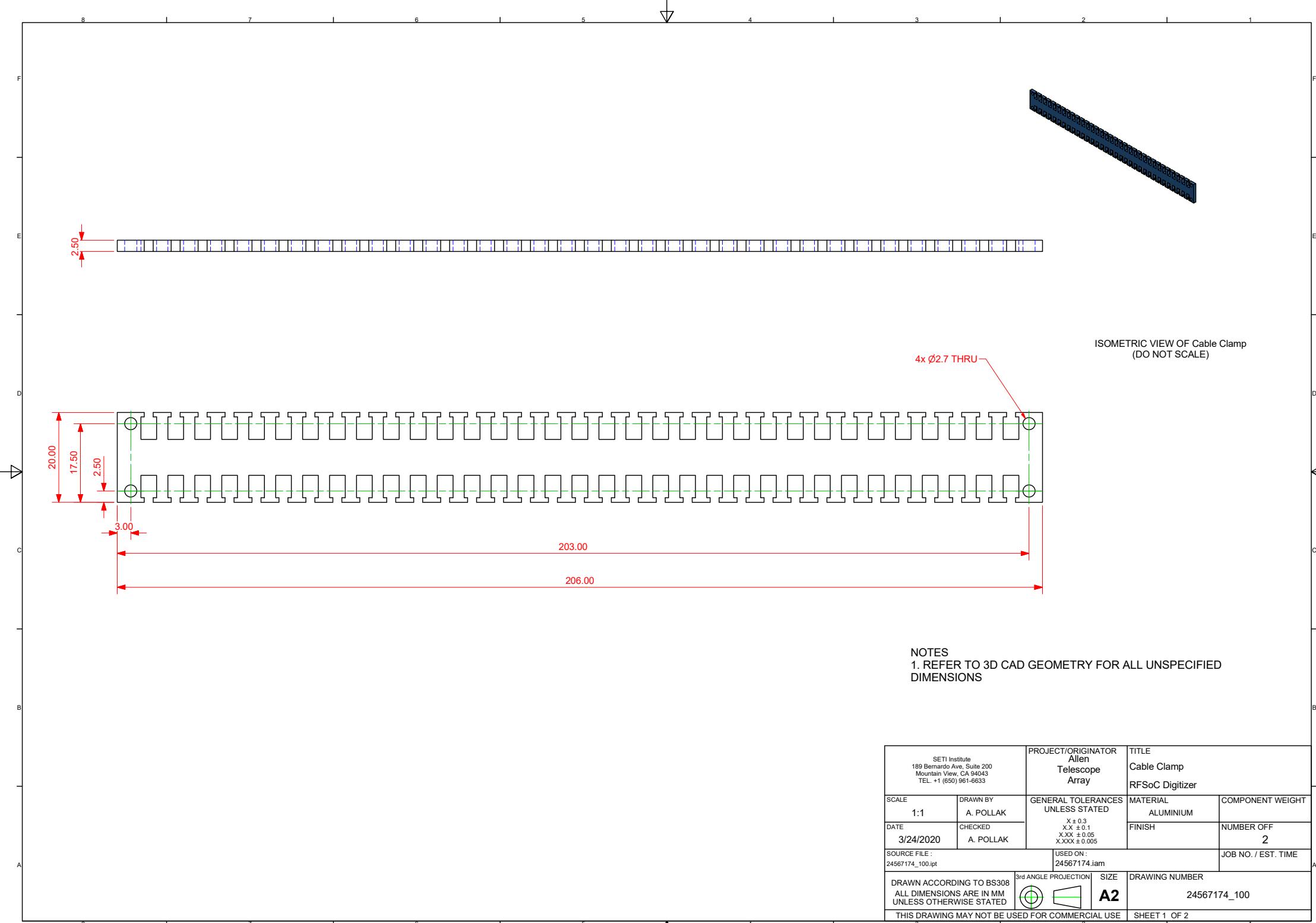


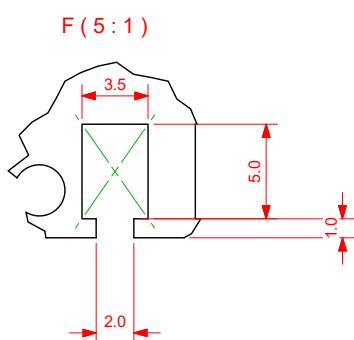
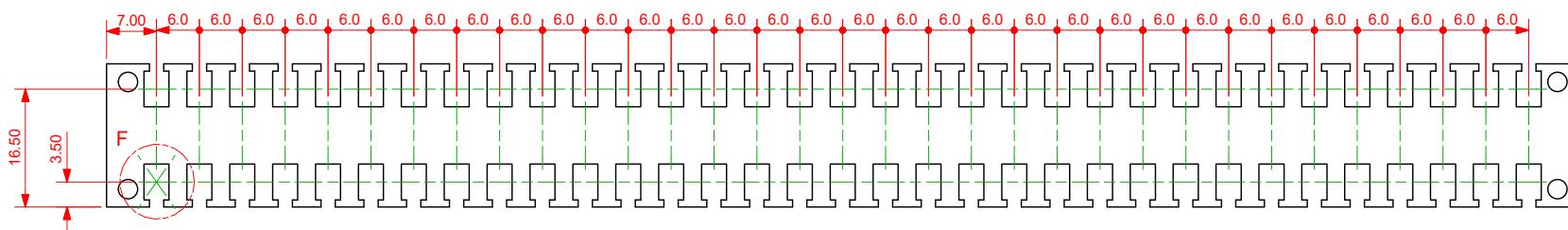


#### NOTES

1. 1MM DEEP CAVITY ON THE REAR SIDE OF THE BASE PLATE.
2. REFER TO 3D CAD GEOMETRY FOR ALL UNSPECIFIED DIMENSIONS

SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043 TEL: +1 (650) 961-6633	PROJECT/ORIGINATOR Allen Telescope Array	TITLE BASE PLATE RFSoC Digitizer
SCALE 1:2	DRAWN BY A. POLLAK	GENERAL TOLERANCES UNLESS STATED $X \pm 0.3$ $XX \pm 0.1$ $XXX \pm 0.05$ $XXXX \pm 0.005$
DATE 30/09/2019	CHECKED A. POLLAK	FINISH
SOURCE FILE : 24567174_99.upt	USED ON : 4567174.iam	NUMBER OFF 1
DRAWN ACCORDING TO BS308 ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE STATED		JOB NO. / EST. TIME
3rd ANGLE PROJECTION	SIZE A2	DRAWING NUMBER 24567174_99
THIS DRAWING MAY NOT BE USED FOR COMMERCIAL USE		
SHEET 4 OF 4		





SETI Institute 189 Bernardo Ave, Suite 200 Mountain View, CA 94043 TEL. +1 (650) 961-6633	PROJECT/ORIGINATOR Allen Telescope Array	TITLE Cable Clamp RFSoC Digitizer
SCALE 1:1	DRAWN BY A. POLLAK	GENERAL TOLERANCES UNLESS STATED $X \pm 0.3$ $XX \pm 0.1$ $XXX \pm 0.05$ $XXXX \pm 0.005$
DATE 3/24/2020	CHECKED A. POLLAK	FINISH
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DRAWN ACCORDING TO BS308 ALL DIMENSIONS ARE IN MM UNLESS OTHERWISE STATED		JOB NO. / EST. TIME
3rd ANGLE PROJECTION	SIZE A2	DRAWING NUMBER 24567174_100
THIS DRAWING MAY NOT BE USED FOR COMMERCIAL USE		
SHEET 2 OF 2		

## B Component List of RFSoC Digitizer Module

Qty	Unit	Description	Manufacturer	PN Manufacturer	Distributor	PN Distributor
1	Each	EuropacPRO kit, heavy design, shielded, with front handles	Schroff	24567-174	Distrelec	110-74-433
1	Each	19" AC/DC switch-mode PSUs, maxpower 180 W, single 12V 13A	Schroff	13100-151	Distrelec	110-89-774
1	Each	Front Panel 13100 SLE 19" AC/DC Switch-Mode PSUs 128.4 mm, nVent Schroff	Schroff	31006-677	Distrelec	110-90-375
1	Each	Coding, PU 10 pack	Schroff	20800-042	Distrelec	110-89-865
1	Pack	Guide Rail Standard Type, Red, 160mm, Pack of 10 pieces	Schroff	24568-361	Distrelec	302-25-177
1	Each	Connector H 15 F, FASTON connection	Schroff	69001-733	Distrelec	110-90-542
1	Each	Front Panel	Front Panel Express, LLC	ATA-AP-24567174_98.fpd		
1	Each	Rear Panel	Front Panel Express, LLC	ATA-AP-24567174_05.fpd		
1	Each	Baseplate	Front Panel Express, LLC	ATA-AP-24567174_99.fpd		
1	Each	Cable Clamp	Front Panel Express, LLC	ATA-AP-24567174_100.fpd		
1	Each	DC Fans DC Fan, High Airflow Series, 80x80	Sunon	PF80251V1-1000U-A99	Mouser	369-PF80251V11UA99
6	Each	Axial Fan, IP20, 12 V, DC, 40 mm, 10 mm	EBM-PAPST	412FM	Mouser	5912-412FM
1	Each	Fan Blower, GB Series Compact, 12 V, DC	SUNON	GB1205PKV1-8AY.GN	Mouser	369-CB1205PKV18AYGN
1	Pack	Screw, SLT, CSK, Steel, BZP, M3X16	TR Fastenings	M316 KSSTMCZ100-	Newark	53M8739
1	Pack	Enclosure Accessory, Grey, Plastic Sleeve	Schroff	21100-464	Newark	74M6491
1	Pack	21101-101 - COLLAR SCREW, PK100	Schroff	21101-101	Newark	74M6493
1	Each	4304.4005 - INLET FILTER, IEC, C14, FKH, 10A	Schruter	43044005	Newark	83T7492
6	Each	Standoffs & Spacers M3 x 25mm HEX	Harwin	R30-3002502	Mouser	855-R30-3002502
25	Each	Standoffs, Hex Male-Female, 20MM, M2.5	RAF	M2115-2545-AL	Mouser	761-M2115-2545-AL
1	Each	DIN rail perforated	Phoenix Contact	801733	Mouser	651-0801733
1	Each	DIN Rail Terminal Blocks PTFIX 12X2.5-NS35ARD 2.5mm <sup>2</sup>	Phoenix Contact	3273158	Mouser	651-3273158
1	Each	DIN Rail Terminal Blocks PTFIX 12X2.5-NS35ABK 2.5mm <sup>2</sup>	Phoenix Contact	3273168	Mouser	651-3273168
1	Each	Headers & Wire Housing 6CKT RECPT HSG	Molex	45559-0002	Mouser	538-45559-0002
100	Each	Headers & Wire Housing MF PLUS HCS CRIMP TE RM. FEM 18-20 GA TIN	Molex	45750-1112	Mouser	538-45750-1112
1	Each	Extraction, Removal & Insertion Tools EXTRACTION TOOL	Molex	11-03-0044	Mouser	538-11-03-0044
1	Each	Crimpers / Crimping Tools MINI-FIT 18-24AWG HAND TOOL	Molex	63819-0901	Mouser	538-63819-0901
16	Each	SMA Female Bulkhead to SSMC Plug Cable 18 Inch Length Using PE-SR405FLJ Coax	Pasternack	PE3C4448-18	Pasternack	PE3C4448-18
1	Each	SMA Female Bulkhead to MCX Plug Right Angle Semi-Flexible Precision Cable 18 Inch Length Using PE-SR405FLJ Coax, LF Solder, RoHS	Pasternack	PE39435-18	Pasternack	PE39435-18
1	Each	SMA Female Bulkhead to SSMC Plug Right Angle Cable 18 Inch Length Using PE-SR405FLJ Coax	Pasternack	PE3C4486-18	Pasternack	PE3C4486-18
5	Each	LED Panel Mount Indicator, Blue, 3.8 VDC, 6 mm, 20 mA	APEM	Q6FTBXXB02E	Mouser	642-Q6FTBXXB02E
2	Pack	SCREW,SECURITY FIXING, M2.5X5, PK100	VERO	173-202579H	Newark	25M0782
1	Pack	Machine Screw, M3, 25 mm	Littlefuse	0239002.HXP	Newark	27AC4115
2	Each	Fuse, Cartridge, Slow Blow, 2 A, 250 V				

## C Interface Board and HTG-ZRF16 board Component List

Qty	Unit	Description	Manufacturer	PN Manufacturer	Distributor	PN Distributor
1	Each	ATA-HTG_ZRF16.GPIO_Board_AP_V1.0	AP			
1	Each	PCB V1.0	AP	ATA-HTG_ZRF16.GPIO_Board_AP_V1.0.zip		
1	Each	Littelfuse 1A T Non-Resettable Surface Mount Fuse, 125 V	Littlefuse	0154001.DRT	Mouser	576-0154001.DRT
1	Each	Fuse, Surface Mount, 1.5 A, NANO 452 Series, 125 VAC, 32 VDC, Time Delay, SMD	Littlefuse	045201.5MRL	Mouser	576-045201.5MRL
1	Each	Surface Mount Tantalum Capacitor, 100 $\mu$ F, 25 V, 2917 [7343 Metric], T491 Series, $\pm 10\%$ , $-55^{\circ}\text{C}$	Kemet	T491X107K025AT	Mouser	80-T491X107K025AT
1	Each	Electrolytic Capacitor, 220 $\mu$ F, 35 V, M Series, $\pm 20\%$ , Radial Leaded, 8 mm	PANASONIC	ECA-1VM221	Mouser	667-ECA-1VM221
1	Each	KEMET C0805C224K1RACTU 220nF Multilayer Ceramic Capacitor MLCC 100V dc $\pm 10\%$ Tolerance SMD	Kemet	C0805C224K1RACTU	Mouser	80-C0805C224K1R
1	Each	KEMET C0805C104K5RACTU 100nF Multilayer Ceramic Capacitor MLCC 50V dc $\pm 10\%$ Tolerance SMD	Kemet	C0805C104K5RACTU	Mouser	80-C0805C104K5R
1	Each	LINEAR VOLT REG, 5V, 1.5A, TO-263-3	Texas Instruments	LM340SX-5.0/NOPB	Mouser	926-LM340SX-5.0/NOPB
5	Each	LED, QuasarBrite, Green, SMD, 1206, 20 mA, 2.2 V, 565 nm	LUMEX	SML-LX1206GW-TR	Mouser	696-SML-LX1206GW
6	Each	LED, QuasarBrite, Yellow, SMD, 1206, 20 mA, 2 V, 590 nm	LUMEX	SML-LX1206SYC-TR	Mouser	696-SML-LX1206SYC
1	Each	Thin Film Resistors - SMD 0805 523ohm	Panasonic	ERA-6AEB5230V	Mouser	667-ERA-6AEB5230V
18	Each	Thin Film Resistors - SMD 0805 150ohms	Panasonic	ERA-6AEB151V	Mouser	667-ERA-6AEB151V
1	Each	Thin Film Resistors - SMD 0805 374ohm	Panasonic	ERA-6AEB3740V	Mouser	667-ERA-6AEB3740V
1	Each	Thin Film Resistors - SMD 0805 1.07Kohm	Panasonic	ERA-6AEB1071V	Mouser	667-ERA-6AEB1071V
6(12)	Each	Thin Film Resistors - SMD 0805 200ohm	Panasonic	ERA-6AEB201V	Mouser	667-ERA-6AEB201V
8	Each	Thin Film Resistors - SMD 0805 4.7Kohms	Panasonic	ERA6AEB472V	Mouser	667-ERA-6AEB472V
2	Each	Optocoupler, Transistor Output, 4 Channel, DIP, 16 Pins, 60 mA, 5.3 kV, 100%	VISHAY	ILQ2	Mouser	782-ILQ2
16	Each	Buffers & Line Drivers Single Schmitt-Trigger Buffer 5-SC70 -40 to 85	Texas Instruments	SN74LVC1G17DCK3	Mouser	595-SN74LVC1G17DCK3
1	Each	DIP Switches / SIP Switches SLIDE ACT 2 POS	Diptronics	NDS-02V	Mouser	113-NDS-02V
1	Each	COMBICON MCV, 3.81mm Pitch, 2 Way, 1 Row, Straight PCB Terminal Block Header	Phoenix Contact	1803426	Mouser	651-1803426
1	Each	2 way cable mount screw terminal, 3.81mm	Phoenix Contact	1803578	Mouser	651-1803578
1	Each	Headers & Wire Housing 2.54mm CGrid Hdr Shr d /Slt .76AuLF 16Ckt	Moex	70246-1602	Mouser	538-70246-1602
1	Each	Headers & Wire Housing 3CKT BRKWKY HDR	Moex	42375-1856	Mouser	538-42375-1856
8	Each	Headers & Wire Housing 2CKT BRKWKY HDR	Moex	42375-2486	Mouser	538-42375-2486
1	Each	Ribbon Cables / IDC Cables 16Ckt	Samtec	IDSD-08-D-06.00	Mouser	200-IDSD08D0600
1	Each	Headers & Wire Housing 3 PIN SIL HOUSING	Harwin	M20-1060300	Mouser	855-M20-1060300
8	Each	Headers & Wire Housing 2 PIN SIL HOUSING	Harwin	M20-1060200	Mouser	855-M20-1060200
1	Each	Headers & Wire Housing F/M CRIMP TERM GOLD/TIN	Harwin	M20-1180042	Mouser	855-M20-1180042
1	Each	Crimpers / Crimping Tools 2.54mm HAND CRIMP TOOL	Harwin	Z20-320	Mouser	855-Z20-320
1	Each	Fan Tubexial 12VDC Square - 45mm L x 45mm H Ball 11.8 CFM (0.330m <sup>3</sup> /min) 2 Wire Leads	Delta Electronics	AFB04512HA	Digi-Key	603-2157-ND
1	Each	Heat Sink 45mm X 45mm X 24.5mm	Advanced Thermal Solutions	ATS-55450W-C1-R0	Digi-Key	ATTS1330-ND
2	Each	Hex Standoff M2.5X0.45 Alum 20mm	RAF	M2115-2545-AL	Digi-Key	1772-2060-ND
2	Each	Mach Screw Pan Slotted M2.5X0.45	Keystone Electronics	29306	Digi-Key	36-29306-ND

## D Interface Board Schematics

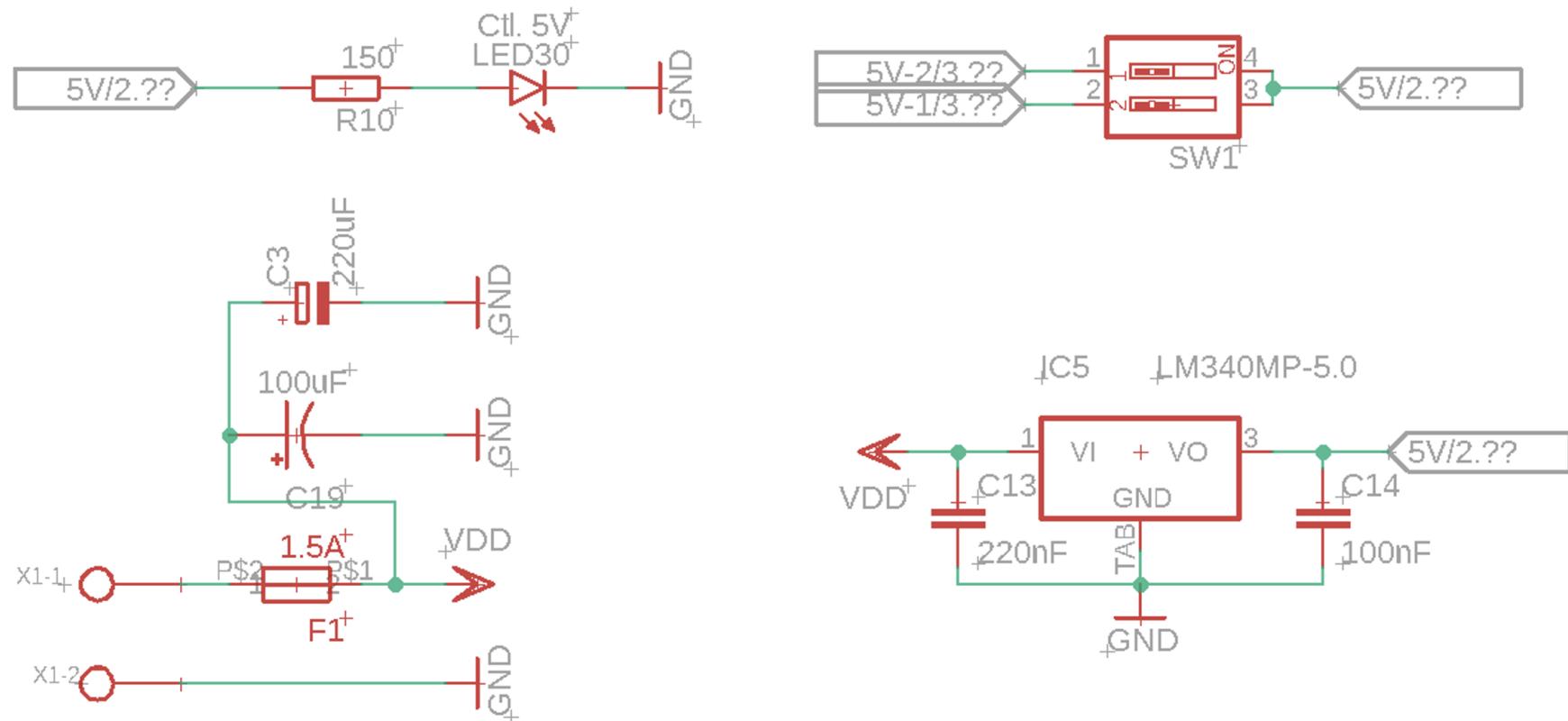


Figure 21: Interface Board Schematic Part 1

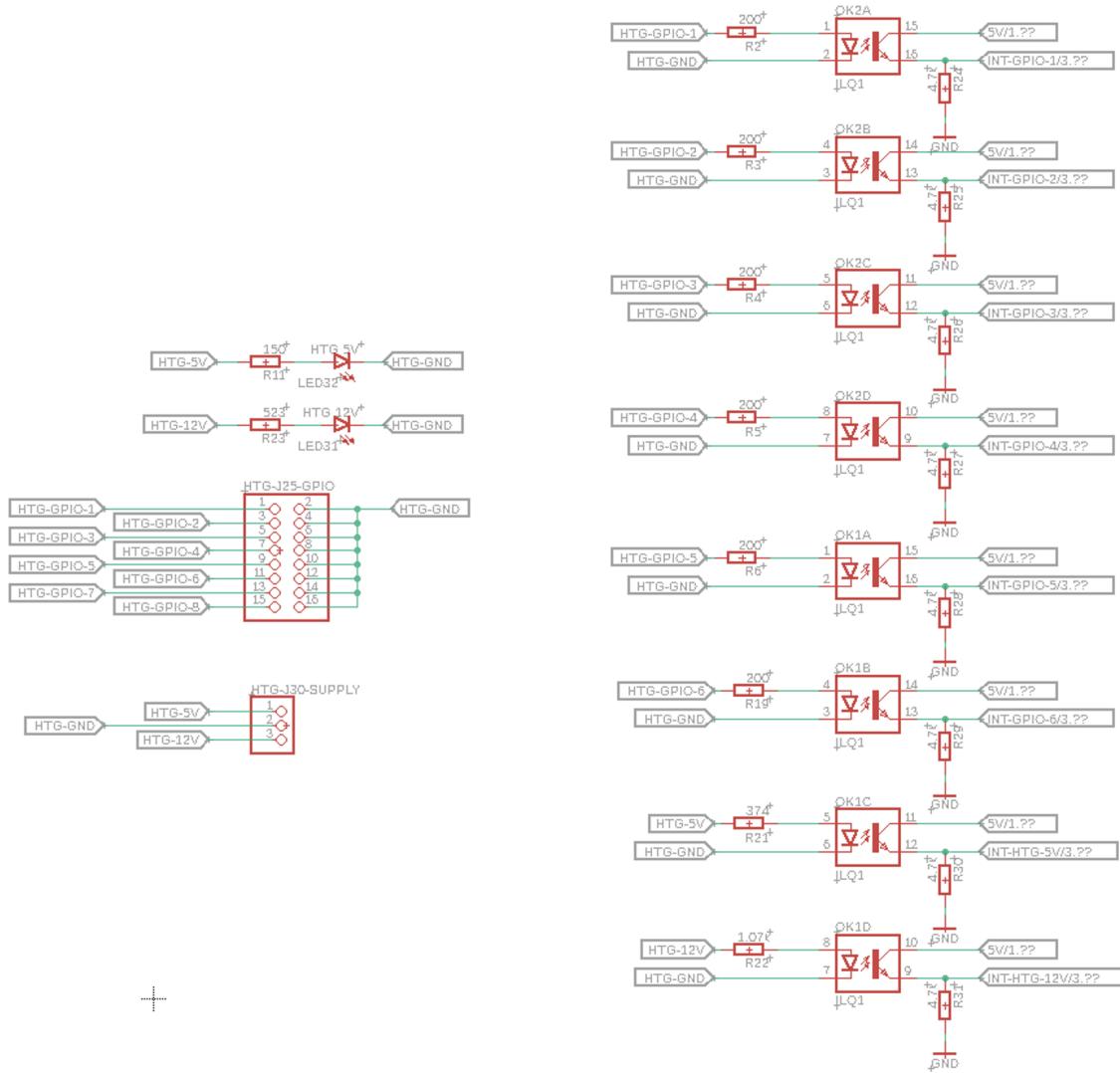


Figure 22: Interface Board Schematic Part 2

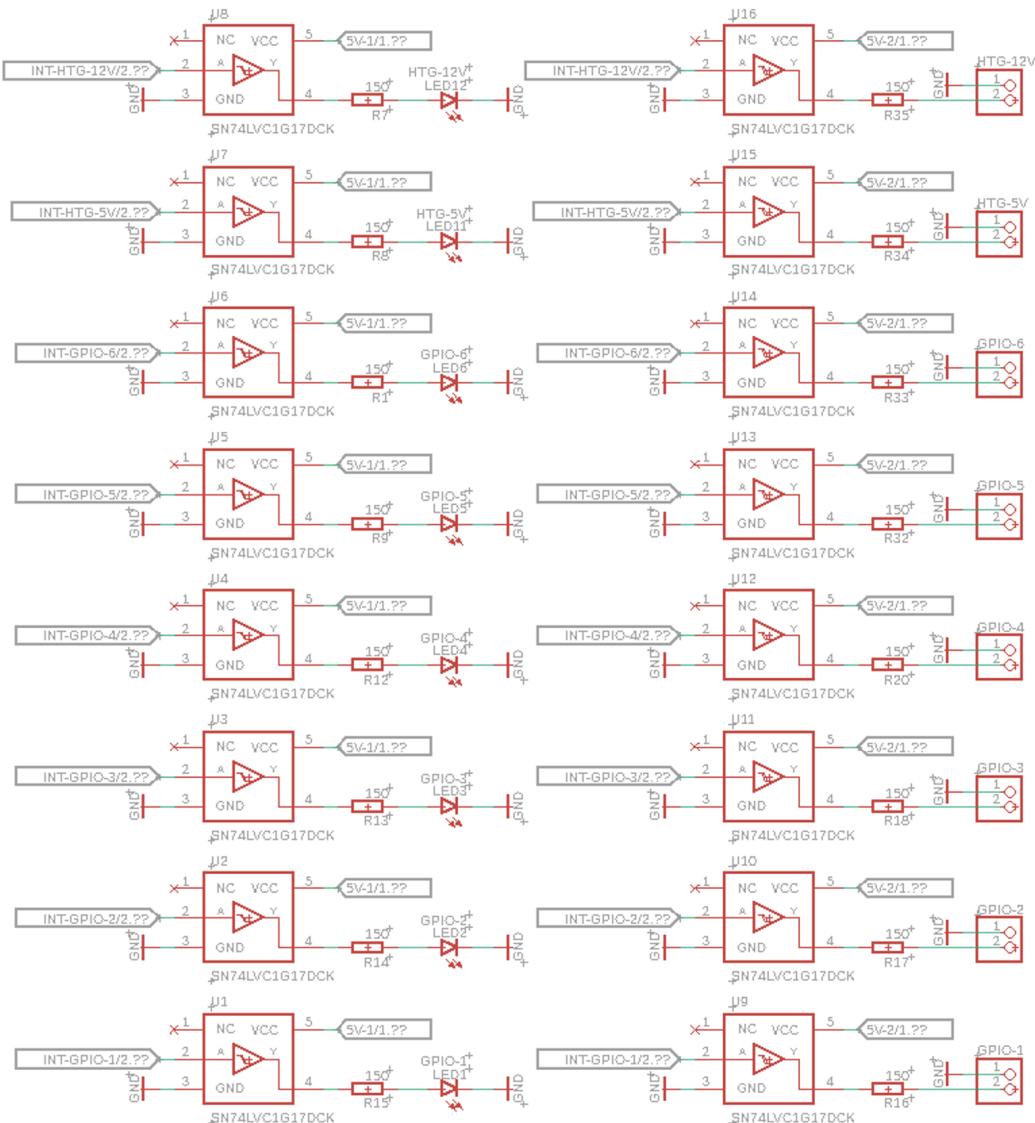


Figure 23: Interface Board Schematic Part 3