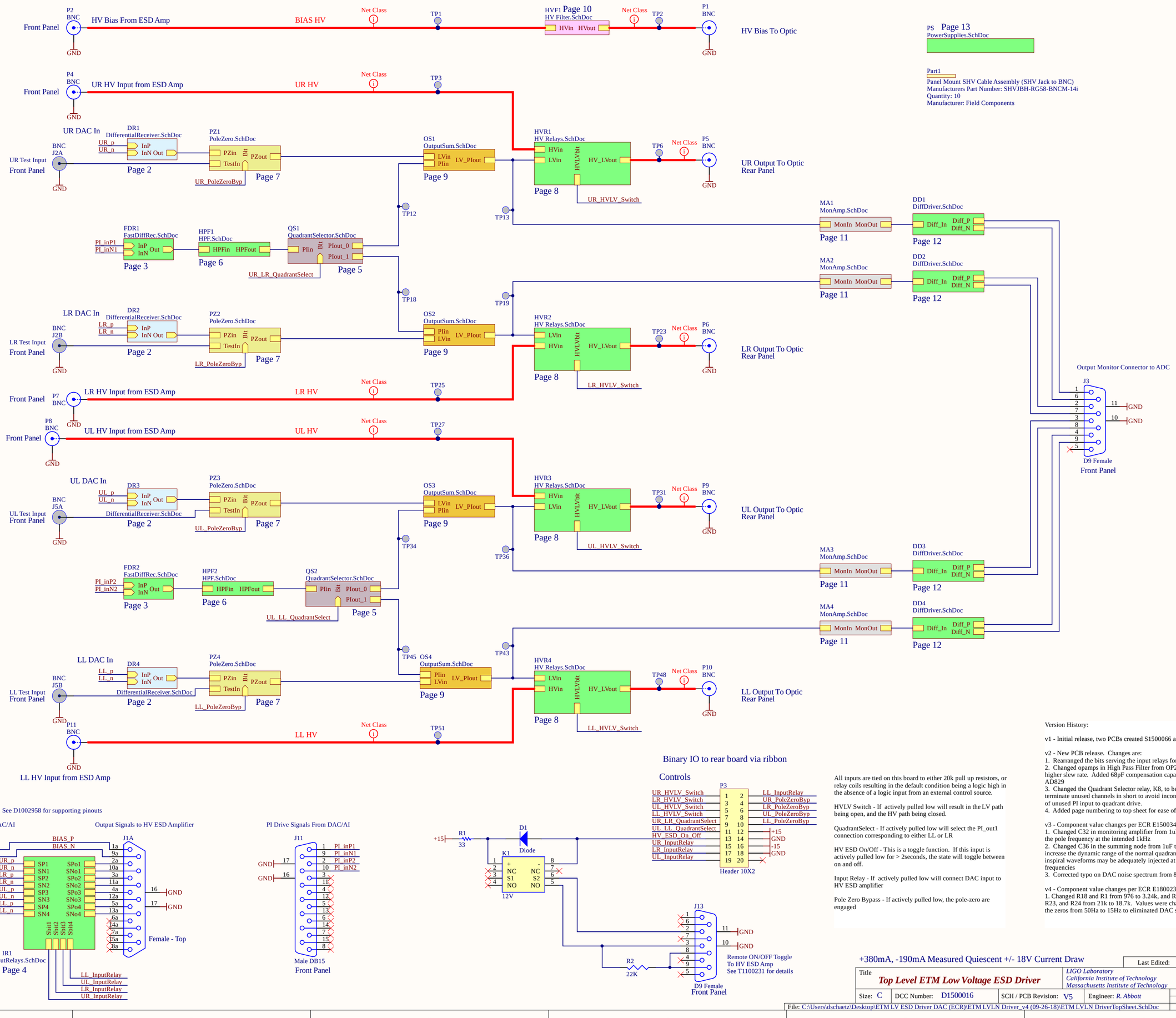
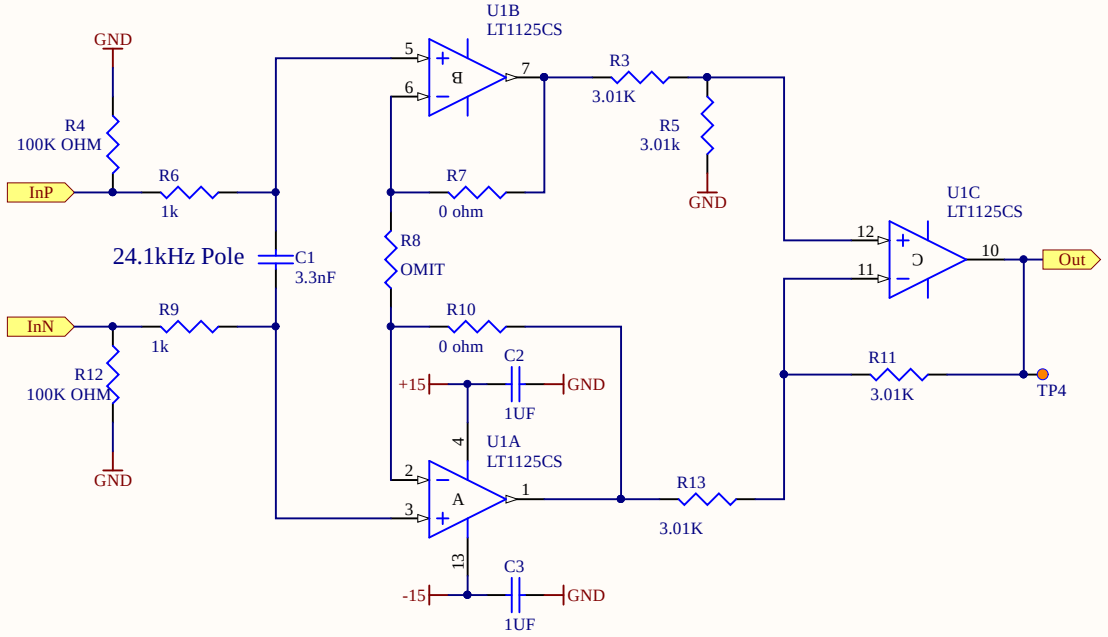
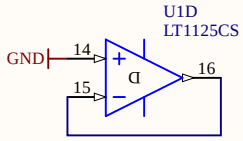

P2 BNC
Front Panel
HV Bias From ESD Amp
BIAS HV
Net Class
TP1
HVF1 Page 10
HV Filter.SchDoc
HVin HVout
Net Class
TP2
P1 BNC
GND
HV Bias To Optic
PS Page 13
PowerSupplies.SchDoc
Part1
Panel Mount SHV Cable Assembly (SHV Jack to BNC)
Manufacturers Part Number: SHVJBH-RG58-BNCM-14i
Quantity: 10
Manufacturer: Field Components
P4 BNC
Front Panel
UR HV Input from ESD Amp
UR HV
Net Class
TP3
GND
UR DAC In
DR1
DifferentialReceiver.SchDoc
UR_p
UR_n
InP
InN Out
PZ1
PoleZero.SchDoc
PZin
TestIn
Bit
PZout
OS1
OutputSum.SchDoc
LVin
PIin
LV_PIout
HVR1
HV Relays.SchDoc
HVin
LVin
HVLVbit
HV_LVout
TP6
Net Class
P5 BNC
BNC J2A
UR Test Input
Front Panel
Page 2
Page 7
Page 9
Page 8
UR_PoleZeroByp
UR_HVLV_Switch
UR Output To Optic
Rear Panel
TP12
TP13
FDR1
FastDiffRec.SchDoc
PI_inP1
PI_inN1
InP
InN Out
HPF1
HPF.SchDoc
HPFin HPFout
QS1
QuadrantSelector.SchDoc
PIin
Bit
PIout_0
PIout_1
Page 3
Page 6
Page 5
UR_LR_QuadrantSelect
MA1
MonAmp.SchDoc
MonIn MonOut
Page 11
DD1
DiffDriver.SchDoc
Diff_In
Diff_P
Diff_N
Page 12
TP18
TP19
LR DAC In
DR2
DifferentialReceiver.SchDoc
LR_p
LR_n
PZ2
PoleZero.SchDoc
OS2
OutputSum.SchDoc
HVR2
HV Relays.SchDoc
TP23
Net Class
P6 BNC
BNC J2B
LR Test Input
Front Panel
LR_PoleZeroByp
LR_HVLV_Switch
LR Output To Optic
Rear Panel
MA2
MonAmp.SchDoc
DD2
DiffDriver.SchDoc
Front Panel
LR HV Input from ESD Amp
LR HV
TP25
P7 BNC
P8 BNC
UL HV Input from ESD Amp
UL HV
TP27
UL DAC In
DR3
PZ3
PoleZero.SchDoc
OS3
OutputSum.SchDoc
HVR3
HV Relays.SchDoc
TP31
P9 BNC
BNC J5A
UL Test Input
UL_PoleZeroByp
UL_HVLV_Switch
UL Output To Optic
Rear Panel
TP34
TP36
FDR2
FastDiffRec.SchDoc
PI_inP2
PI_inN2
HPF2
HPF.SchDoc
QS2
QuadrantSelector.SchDoc
UL_LL_QuadrantSelect
MA3
MonAmp.SchDoc
DD3
DiffDriver.SchDoc
LL DAC In
DR4
PZ4
PoleZero.SchDoc
OS4
OutputSum.SchDoc
HVR4
HV Relays.SchDoc
TP48
P10 BNC
BNC J5B
LL Test Input
LL_PoleZeroByp
LL_HVLV_Switch
LL Output To Optic
Rear Panel
TP45
TP43
MA4
MonAmp.SchDoc
DD4
DiffDriver.SchDoc
P11 BNC
LL HV
TP51
LL HV Input from ESD Amp
Output Monitor Connector to ADC
J3
D9 Female
Front Panel
Binary IO to rear board via ribbon
Controls
P3
Header 10X2
UR_HVLV_Switch
LR_HVLV_Switch
UL_HVLV_Switch
LL_HVLV_Switch
UR_LR_QuadrantSelect
UL_LL_QuadrantSelect
HV_ESD_On_Off
UR_InputRelay
LR_InputRelay
UL_InputRelay
LL_InputRelay
UR_PoleZeroByp
LR_PoleZeroByp
UL_PoleZeroByp
LL_PoleZeroByp
+15
GND
-15
GND
All inputs are tied on this board to either 20k pull up resistors, or relay coils resulting in the default condition being a logic high in the absence of a logic input from an external control source.
HVLV Switch - If actively pulled low will result in the LV path being open, and the HV path being closed.
QuadrantSelect - If actively pulled low will select the PI_out1 connection corresponding to either LL or LR
HV ESD On/Off - This is a toggle function. If this input is actively pulled low for > 2seconds, the state will toggle between on and off.
Input Relay - If actively pulled low will connect DAC input to HV ESD amplifier
Pole Zero Bypass - If actively pulled low, the pole-zero are engaged
Version History:
v1 - Initial release, two PCBs created S1500066 and S1500067
v2 - New PCB release. Changes are:
1. Rearranged the bits serving the input relays for better mapping.
2. Changed opamps in High Pass Filter from OP27 to AD829 for higher slew rate. Added 68pF compensation capacitors for AD829
3. Changed the Quadrant Selector relay, K8, to be able to terminate unused channels in short to avoid inconsistent loading of unused PI input to quadrant drive.
4. Added page numbering to top sheet for ease of browsing
v3 - Component value changes per ECR E1500341
1. Changed C32 in monitoring amplifier from 1uF to 10nF to put the pole frequency at the intended 1kHz
2. Changed C36 in the summing node from 1uF to 0.047uF to increase the dynamic range of the normal quadrant path such that inspiral waveforms may be adequately injected at higher frequencies
3. Corrected typo on DAC noise spectrum from 800uV to 800nV
v4 - Component value changes per ECR E1800233
1. Changed R18 and R1 from 976 to 3.24k, and R20, R21, R22, R23, and R24 from 21k to 18.7k. Values were changed to move the zeros from 50Ha to 15Hz to eliminated DAC saturations
See D1002958 for supporting pinouts
ESD Quadrant Drive Signals From DAC/AI
Output Signals to HV ESD Amplifier
J1B
J1A
BIAS_P
BIAS_N
SP1 SP2 SN1 SN2 SP3 SN3 SP4 SN4
SPo1 SPo2 SNo1 SNo2 SPo3 SNo3 SPo4 SNo4
Shit1 Shit2 Shit3 Shit4
Male - Bottom
Female - Top
IR1
InputRelays.SchDoc
Page 4
LL_InputRelay
UL_InputRelay
LR_InputRelay
UR_InputRelay
PI Drive Signals From DAC/AI
J11
PI_inP1
PI_inN1
PI_inP2
PI_inN2
Male DB15
Front Panel
+15
R1
33
D1
Diode
K1
NC NC
S1 S2
NO NO
12V
R2
22K
J13
Remote ON/OFF Toggle
To HV ESD Amp
See T1100231 for details
+380mA, -190mA Measured Quiescent +/- 18V Current Draw
Last Edited: 10/29/2018
Title
Top Level ETM Low Voltage ESD Driver
LIGO Laboratory
California Institute of Technology
Massachusetts Institute of Technology
LIGO
Size: C
DCC Number: D1500016
SCH / PCB Revision: V5
Engineer: R. Abbott
Date: 10/30/2018
Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\ETM LVLN DriverTopSheet.SchDoc
Sheet 1 of 15

Overall Gain = 1from InP-InN to Out
Ex. 10V battery across input = 10V from Out to GND



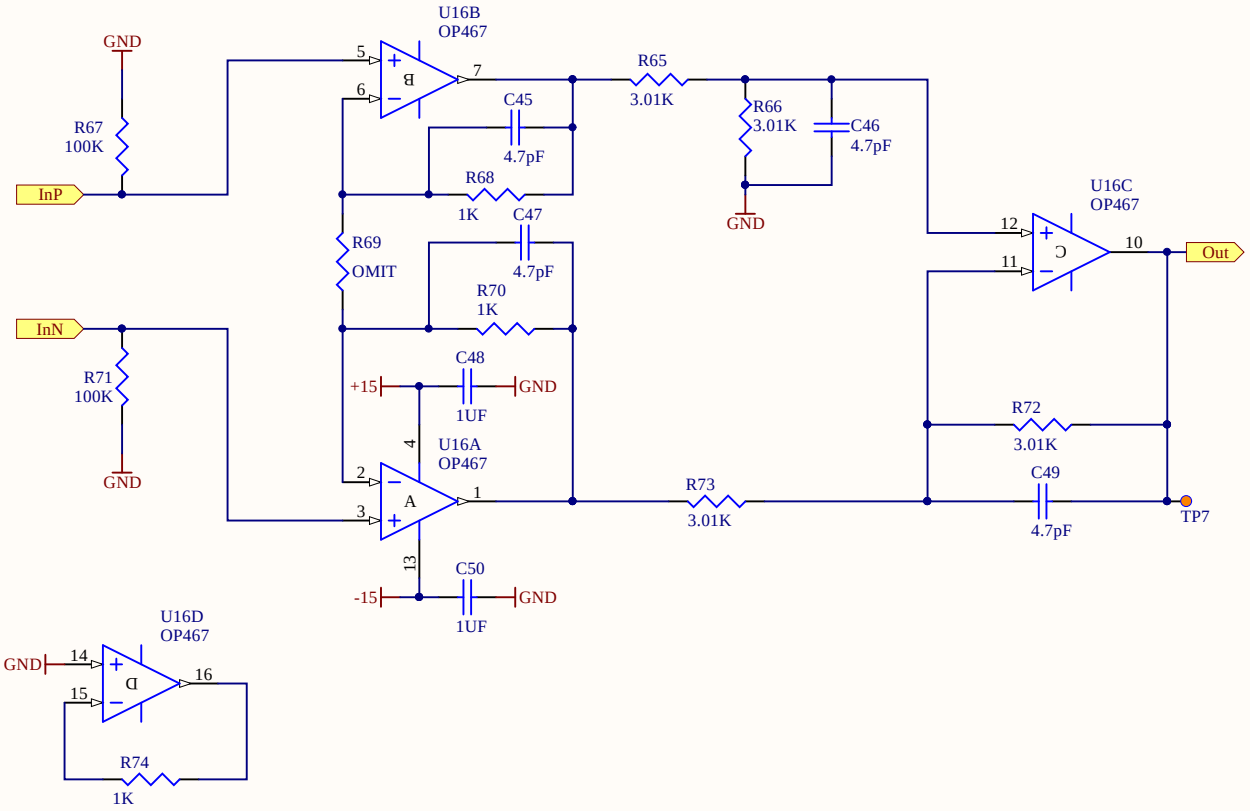


The 24.1kHz RC filter is there to cut high frequency noise to prevent slew rate limiting. Overall gain is 1 such that 10 volts peak from DAC yields 10v wrt ground at output

Checked All

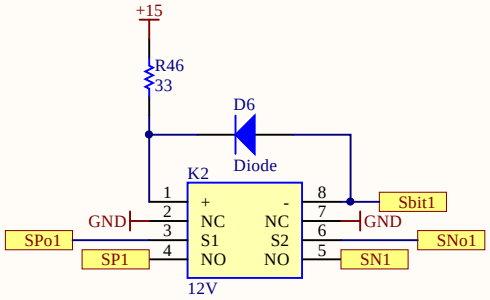
Title: *Differential Receiver*				Last Edited: 10/29/2018
				LIGO Laboratory *California Institute of Technology* *Massachusetts Institute of Technology*
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\DifferentialReceiver.SchDoc				Sheet 2 of 15

Overall Gain = 1from InP-InN to Out
Ex. 10V battery across input = 10V from Out to GND

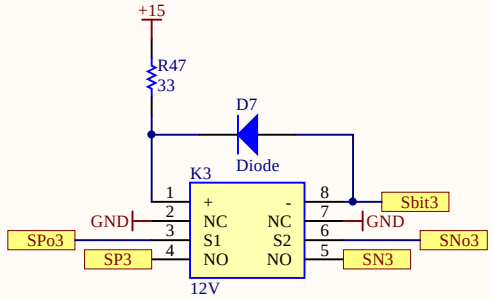


Checked All

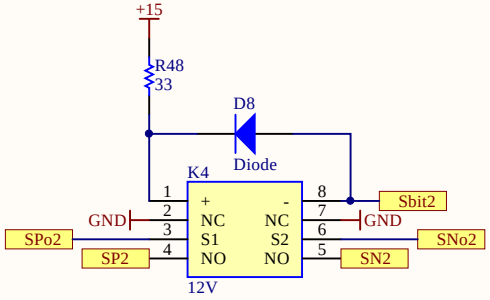
Title: *Fast Differential Receiver*			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Last Edited: 10/29/2018 Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\FastDiffRec.SchDoc				Sheet 3 of 15



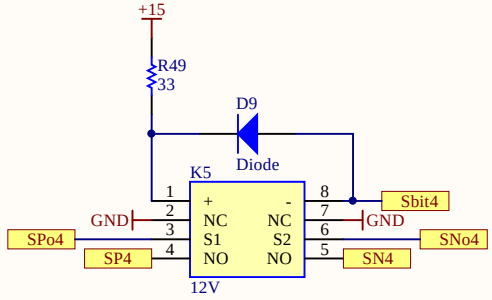
UR



UL



LR



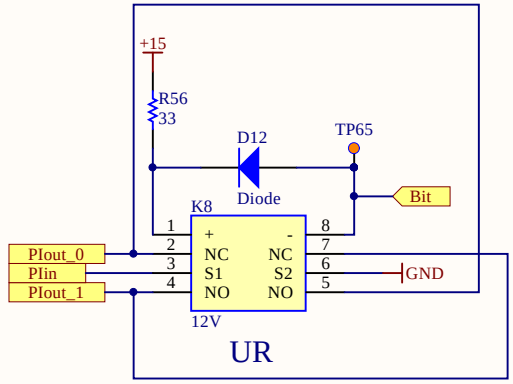
LL

These relays are used to disconnect the applied differential DAC signals from the high voltage ESD amplifier after transition to low voltage control.

Checked All

Last Edited: 10/29/2018

Title: *Input Relays*			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\InputRelays.SchDoc				Sheet 4 of 15



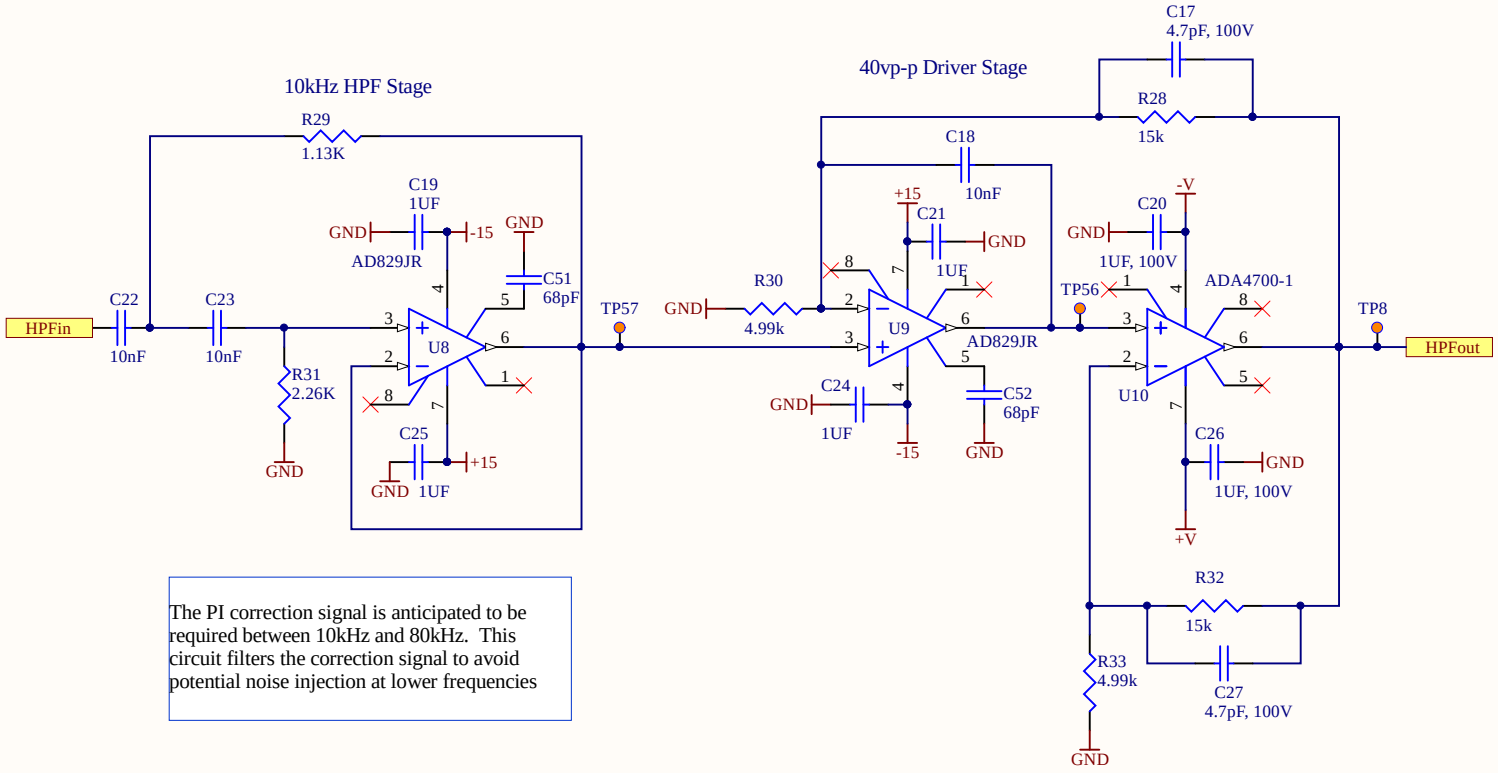
Only a total of 2 ADC channels were available within the existing SUS topology for the PI input. This switch allows the user to select which two quadrants of a test mass will receive the PI correction signals.

The grounded pin on S2 terminates the unused leg of the PI output path to mimic the voltage source that would have been connected. Failure to do this would result in a change in the transfer function of the passive summing network.

Bit control input pulling low will select the PIout_1 path and vice versa

Last Edited: 10/29/2018				
Title: ***Quadrant Selector***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\QuadrantSelector.SchDoc				Sheet 5 of 15

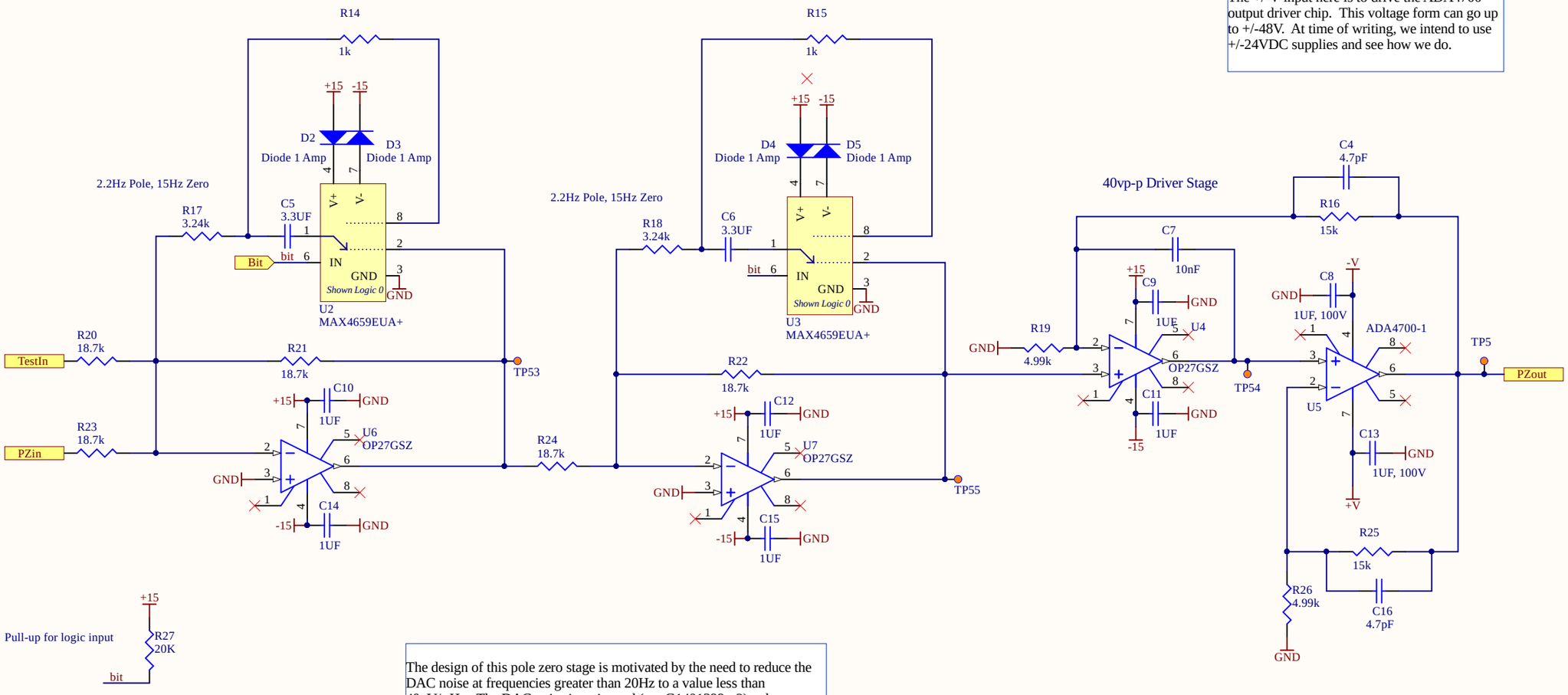
The +/-V input here is to drive the ADA4700 output driver chip. This voltage form can go up to +/-48V. At time of writing, we intend to use +/-24VDC supplies and see how we do.



The PI correction signal is anticipated to be required between 10kHz and 80kHz. This circuit filters the correction signal to avoid potential noise injection at lower frequencies

Last Edited: 10/29/2018				
Title: ***10kHz Sallen Key HPF***	*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*			LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\HPF.SchDoc				Sheet 6 of 15

The +/-V input here is to drive the ADA4700 output driver chip. This voltage form can go up to +/-48V. At time of writing, we intend to use +/-24VDC supplies and see how we do.

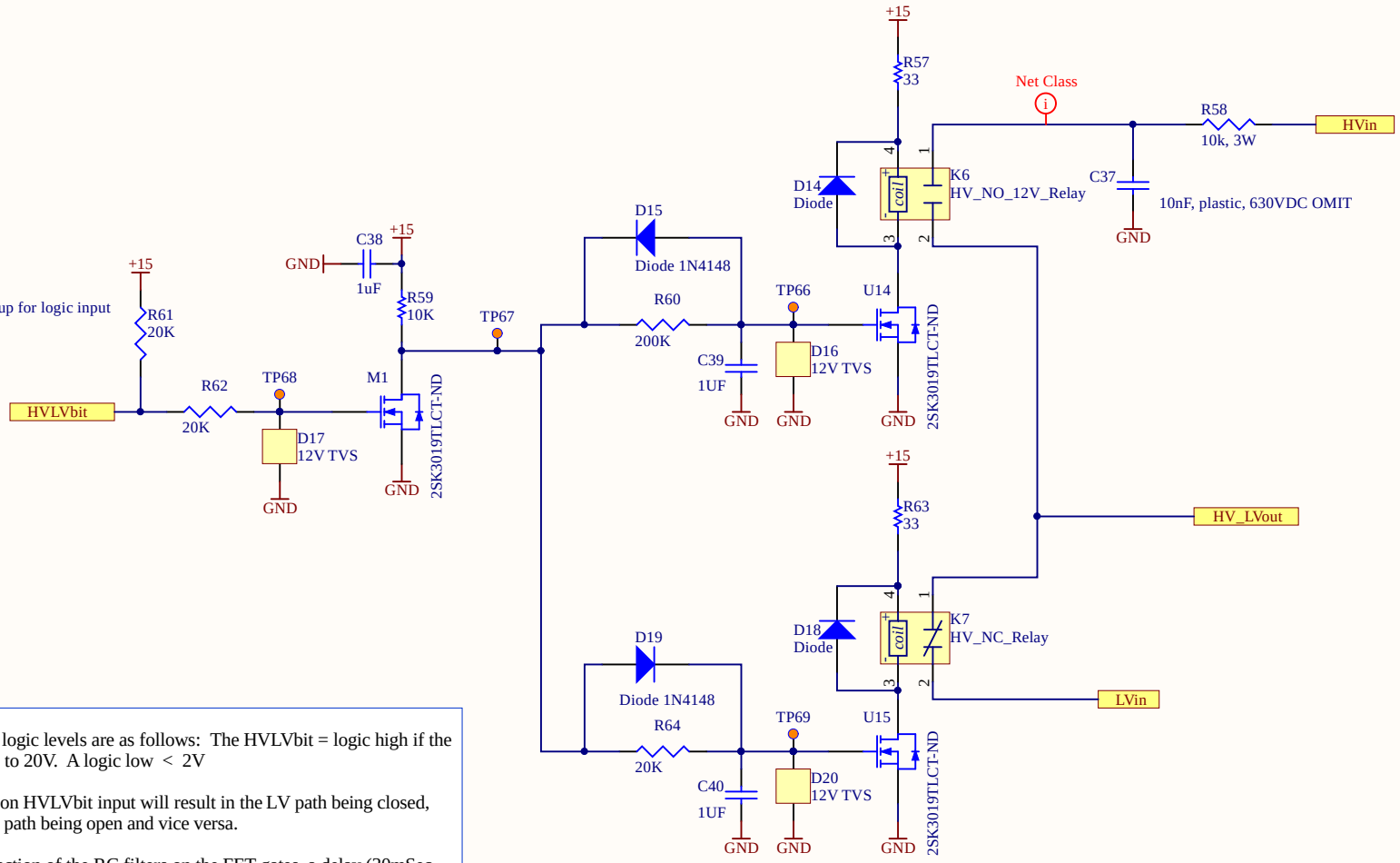


The design of this pole zero stage is motivated by the need to reduce the DAC noise at frequencies greater than 20Hz to a value less than 40nV/rtHz. The DAC noise is estimated (per G1401399-v2) to be 800nV/rtHz at 20 Hz. The choice of pole and zero frequency above results in a predicted circuit output noise of 28nV/rtHz at 20Hz in the presence of the anticipated DAC noise. The zero preserves some drive dynamic range at intermediate frequencies.

The ADA4700-1 stage provides the capability to increase the dynamic range to 40vp-p

Checked All

Last Edited: *10/29/2018*				
Title: ***Pole-Zero and Driver***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: B	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:46 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\PoleZero.SchDoc				Sheet 7 of 15



Acceptable logic levels are as follows: The HVLVbit = logic high if the voltage is 5 to 20V. A logic low < 2V

Logic high on HVLVbit input will result in the LV path being closed, and the HV path being open and vice versa.

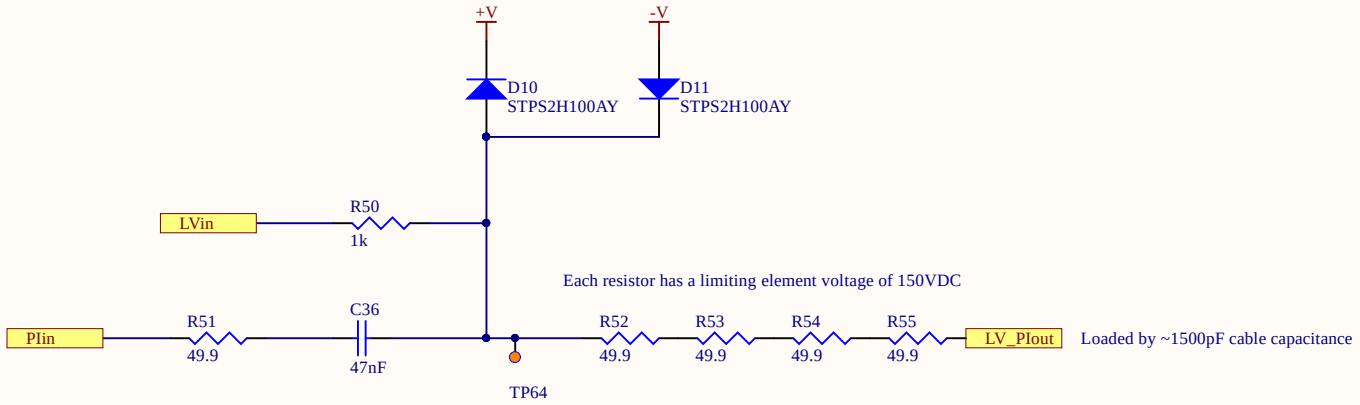
Due to the action of the RC filters on the FET gates, a delay (30mSec minimum) is introduced ensuring the HV path will never be closed while the LV path is closed. Failure to do this would connect the HV circuit to the LV which would be bad.

The uncommanded state results in the HV being OFF and the LV being ON

The 10nF HV capacitor on the output can be optionally utilized to lower the source impedance in the event that is useful.

Last Edited: 10/29/2018

Title: ***High & Low Voltage Transition Relays***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:47 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\HV Relays.SchDoc				Sheet 8 of 15

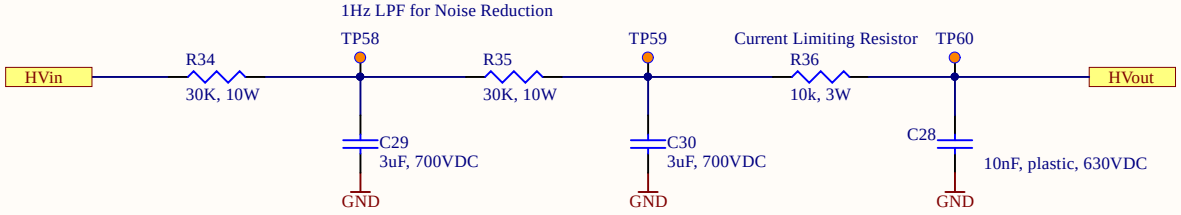


This summing node combines the low frequency DC coupled signals present in the normal feedback path to each quadrant with the parametric instability correction signal. The summing was done passively to allow greater dynamic range than that afforded by an active summing stage. The STPS2H100AY diodes and output 200 ohm resistor string dissipate the potential stored charge present on the output cable leading to the vacuum system and limit the instantaneous current to be less than 2 amperes assuming worst case cable charge of 400VDC and 1500pF cable capacity.

Checked All

Last Edited: 10/29/2018				
Title: *Output Summing Node*	*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*			LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:47 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\OutputSum.SchDoc				Sheet 9 of 15

This filter can store charge. Assume the capacitors are charged until positively discharged and measured.

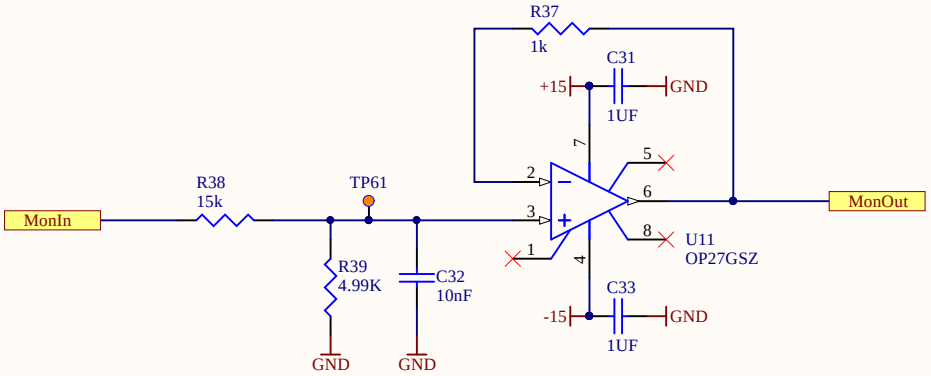


From T1400406 by Rai Weiss, this filter lowers the voltage noise on the bias path. This path has no requirement for fast frequency response beyond the ability to set the bias voltage on a human timescale.

An additional 10k series resistor is conservatively included as a hedge against an in-vacuum discharge event. The 10nF HV capacitor on the output can be optionally utilized to lower the source impedance to the bias electrode in the event that is useful.

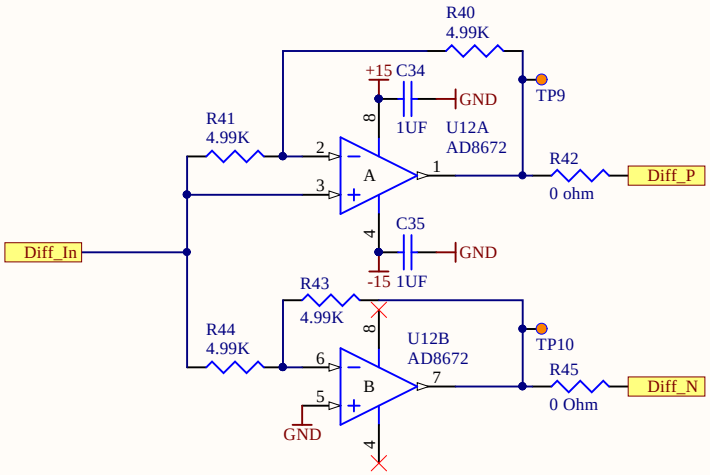
Last Edited: 10/29/2018				
Title: ***High Voltage Bias Filter***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:47 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\HV Filter.SchDoc				Sheet 10 of 15

The large dynamic range of the output drivers (40vp-p) requires this monitor to attenuate the input signal. A pole at 1kHz is included for further attenuation of the PI band.



Title: *Monitoring Amplifier*				*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Last Edited: 10/29/2018 Date: 10/30/2018 Time: 11:17:47 AM Sheet 11 of 15

File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\MonAmp.SchDoc

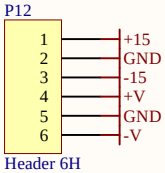


Typical LIGO differential driver circuit for the monitor signals.

Title: ***Differential Driver***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	Last Edited: 10/29/2018
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:47 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\DiffDriver.SchDoc				Sheet 12 of 15

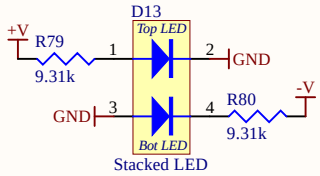
Part2
Pins for female molex connector
WM2307-ND
Quantity: 6

Part3
Mating 6 pin molex connector
WM2126-ND

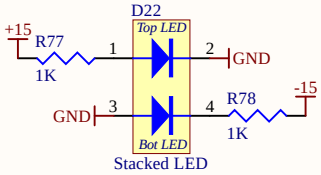


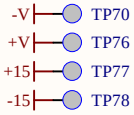
The +/-V input here is to drive the ADA4700 output driver chip. This voltage form can go up to +/-48V. At time of writing, we intend to use +/-24VDC supplies and see how we do.

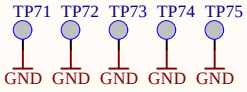
+V/-V Power LED

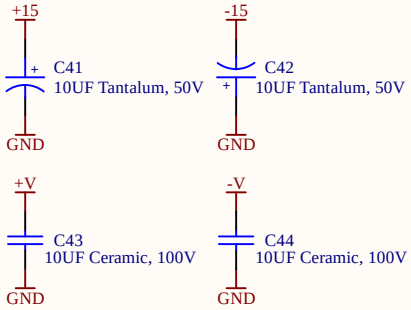


15VDC Power LED









Last Edited: 10/29/2018

Title: ***Power Supplies***			*LIGO Laboratory* *California Institute of Technology* *Massachusetts Institute of Technology*	LIGO
Size: A	DCC Number: D1500016	Revision: V5	Engineer: *R. Abbott*	Date: 10/30/2018 Time: 11:17:47 AM
File: C:\Users\dschaetz\Desktop\ETM LV ESD Driver DAC (ECR)\ETM LVLN Driver_v4 (09-26-18)\PowerSupplies.SchDoc				Sheet 13 of 15

Line #	Name	Description	Designator	Quantity	Value	Supplier 1	Supplier Part Number 1	Manufacturer 1	Manufacturer Part Number 1	Manufacturer Lifecycle 1	Supplier Unit Price 1	Supplier Subtotal 1
1	3.3nF	CAP 3.3nF 50V PPS 1206	C1_DR1, C1_DR2, C1_DR3, C1_DR4	4	3.3nF	Digi-Key	PCF1302CT-ND	Panasonic	ECH-U1H332GX5	Manual Solution	0.45	1.8
2	1UF	CAP 1.0UF 50V CERAMIC F 1206	C2_DR1, C2_DR2, C2_DR3, C2_DR4, C3_DR1, C3_DR2, C3_DR3, C3_DR4, C48_FDR1, C48_FDR2, C50_FDR1, C50_FDR2	12	1UF	Digi-Key	1276-1204-1-ND	Samsung	CL31F105ZBFNNNE	Manual Solution	0.174	2.09
3	4.7pF		C4_PZ1, C4_PZ2, C4_PZ3, C4_PZ4, C16_PZ1, C16_PZ2, C16_PZ3, C16_PZ4	8		Arrow	12065A4R7CAT2A	Kyocera AVX	12065A4R7CAT2A	Manual Solution	0.1548	1.55
4	3.3UF		C5_PZ1, C5_PZ2, C5_PZ3, C5_PZ4, C6_PZ1, C6_PZ2, C6_PZ3, C6_PZ4	8		Arrow	ECQ-E1335KF	Panasonic	ECQ-E1335KF	Manual Solution	1	8.04
5	10nF		C7_PZ1, C7_PZ2, C7_PZ3, C7_PZ4, C18_HPF1, C18_HPF2	6		Digi-Key	PCF1340CT-ND	Panasonic	ECHU-1H103JX5	Manual Solution	0.48	2.88
6	1UF, 100V	1uF, 100V, 1206 Capacitor	C8_PZ1, C8_PZ2, C8_PZ3, C8_PZ4, C13_PZ1, C13_PZ2, C13_PZ3, C13_PZ4, C20_HPF1, C20_HPF2, C26_HPF1, C26_HPF2	12		Digi-Key	490-3909-1-ND	Murata	GRM31CR72A105KA01L	Manual Solution	0.66	7.92
7	1UF		C9_PZ1, C9_PZ2, C9_PZ3, C9_PZ4, C10_PZ1, C10_PZ2, C10_PZ3, C10_PZ4, C11_PZ1, C11_PZ2, C11_PZ3, C11_PZ4, C12_PZ1, C12_PZ2, C12_PZ3, C12_PZ4, C14_PZ1, C14_PZ2, C14_PZ3, C14_PZ4, C15_PZ1, C15_PZ2, C15_PZ3, C15_PZ4, C19_HPF1, C19_HPF2, C21_HPF1, C21_HPF2, C24_HPF1, C24_HPF2, C25_HPF1, C25_HPF2, C31_MA1, C31_MA2, C31_MA3, C31_MA4, C33_MA1, C33_MA2, C33_MA3, C33_MA4, C34_DD1, C34_DD2, C34_DD3, C34_DD4, C35_DD1, C35_DD2, C35_DD3, C35_DD4	48				KEMET	C1206C105K5RACTU	Manual Solution		
8	4.7pF, 100V		C17_HPF1, C17_HPF2, C27_HPF1, C27_HPF2	4		Digi-Key	399-9251-1-ND	KEMET	C0805C479D1GACTU	Manual Solution	0.36	1.44
9	10nF		C22_HPF1, C22_HPF2, C23_HPF1, C23_HPF2	4		Digi-Key	PCF1340CT-ND	Panasonic	ECH-U1H103JX5	Manual Solution	0.48	1.92
10	10nF, plastic, 630VDC		C28	1		Digi-Key	399-5482-1-ND	KEMET	LDEPD2100KA5N00	Manual Solution	1.09	1.09
11	3uF, 700VDC	10uF, 700VDC Capacitor	C29, C30	2		Digi-Key	BC2786-ND	Vishay	MKP1848S53070JK2A	Manual Solution	3.44	6.88
12	10nF	10nF Plastic Cap	C32_MA1, C32_MA2, C32_MA3, C32_MA4	4		Digi-Key	EF2103-ND	Panasonic	ECQ-E2103KF	Manual Solution	0.33	1.32
13	47nF		C36_OS1, C36_OS2, C36_OS3, C36_OS4	4		Digi-Key	P14612-ND	Panasonic	ECQ-E2473JF	Manual Solution	0.36	1.44
14	10nF, plastic, 630VDC OMIT	An optional capacitor not stuffed initially	C37_HVR1, C37_HVR2, C37_HVR3, C37_HVR4	4		Digi-Key	399-5482-1-ND	KEMET	LDEPD2100KA5N00	Manual Solution	1.09	4.36
15	1uF	Capacitor	C38_HVR1, C38_HVR2, C38_HVR3, C38_HVR4	4	1uF	Digi-Key	EF1105-ND	Panasonic	ECQ-E1105KF	Manual Solution	0.65	2.6
16	1UF		C39_HVR1, C39_HVR2, C39_HVR3, C39_HVR4, C40_HVR1, C40_HVR2, C40_HVR3, C40_HVR4	8				KEMET	C1206C105K5RACTU	Manual Solution		
17	10UF Tantalum, 50V	Tantalum Capacitor	C41, C42	2		Digi-Key	478-2380-1-ND	Kyocera AVX	TAJD106K050RNJ	Manual Solution	3.93	7.86
18	10UF Ceramic, 100V		C43, C44	2		Digi-Key	445-13408-1-ND	TDK	C5750X7S2A106K230KB	Manual Solution	2.58	5.16
19	4.7pF		C45_FDR1, C45_FDR2, C46_FDR1, C46_FDR2, C47_FDR1, C47_FDR2, C49_FDR1, C49_FDR2	8	4.7pF	Digi-Key	478-1464-1-ND	Kyocera AVX	12065A4R7CAT2A	Manual Solution	0.274	2.74
20	68pF		C51_HPF1, C51_HPF2, C52_HPF1, C52_HPF2	4				KEMET	C1206C680J5GACTU	Manual Solution		
21	Diode	Default Diode	D1, D6-D9, D12_QS1, D12_QS2, D14_HVR1, D14_HVR2, D14_HVR3, D14_HVR4, D18_HVR1, D18_HVR2, D18_HVR3, D18_HVR4	15		Digi-Key	SE20AFJ-M3/6AGICT-ND	Vishay Semiconductors	SE20AFJ-M3/6A	Manual Solution	0.326	4.89
22	60V, 1A Schottky	Diode 1 Amp	D2_PZ1, D2_PZ2, D2_PZ3, D2_PZ4, D3_PZ1, D3_PZ2, D3_PZ3, D3_PZ4, D4_PZ1, D4_PZ2, D4_PZ3, D4_PZ4, D5_PZ1, D5_PZ2, D5_PZ3, D5_PZ4	16	Diode 1 Amp	Digi-Key	RB160MM-60CT-ND	Rohm	RB160MM-60TR	Manual Solution	0.389	6.22
23	STPS2H100AY	Schottky Diode	D10_OS1, D10_OS2, D10_OS3, D10_OS4, D11_OS1, D11_OS2, D11_OS3, D11_OS4	8		Digi-Key	497-11102-1-ND	STMicroelectronics	STPS2H100AY	Manual Solution	0.89	7.12
24	Stacked LED	Dual Green LED	D13, D22	2	Stacked LED	Digi-Key	67-1321-ND	Lumex	SSF-LXH240GGD	Manual Solution	1.09	2.18
25	Diode 1N4148	High Conductance Fast Diode	D15_HVR1, D15_HVR2, D15_HVR3, D15_HVR4, D19_HVR1, D19_HVR2, D19_HVR3, D19_HVR4	8		Digi-Key	1N4148WTPMSCT-ND	MCC	1N4148W-TP	Manual Solution	0.14	1.12
26	12V TVS	12V Bi-directional Transient Voltage Suppressor	D16_HVR1, D16_HVR2, D16_HVR3, D16_HVR4, D17_HVR1, D17_HVR2, D17_HVR3, D17_HVR4, D20_HVR1, D20_HVR2, D20_HVR3, D20_HVR4	12		Digi-Key	SMAJ12CALFCT-ND	Littelfuse	SMAJ12CA	Manual Solution	0.363	4.36
27	D15 Female Top, Male Bottom	Stacked D-15 Female Top, Male Bottom, Norcomp 178 Series	J1	1		Digi-Key	1115FME-ND	NorComp	178-015-313R571	Manual Solution	9.34	9.34
28	BNC	Stacked Dual BNC	J2, J5	2		Digi-Key	991-1023-ND	Winchester Bomar	364A2595	Manual Solution	8.59	17.18
29	D9 Female	Receptacle Assembly, 9 Position, Right Angle	J3, J13	2		Digi-Key	A32117-ND	TE Connectivity	5747844-4	Manual Solution	2.42	4.84
30	Male DB15	Receptacle Assembly, 15 Position, Right Angle	J11	1		Digi-Key	6E17C-015P-AJ-121-ND	Amphenol Commercial	6E17C015PAJ121	Manual Solution	6.41	6.41
31	12V	12V DPDT Omron Relay	K1-K5, K8_QS1, K8_QS2	7				Omron	G6K-2F-TRDC12	Manual Solution		
32	HV_NO_12V_Relay		K6_HVR1, K6_HVR2, K6_HVR3, K6_HVR4	4		Digi-Key	725-1047-ND	Cynergy3	DAR71210	Manual Solution	35.06	140.24
33	HV_NC_Relay		K7_HVR1, K7_HVR2, K7_HVR3, K7_HVR4	4		Digi-Key	725-1049-ND	Cynergy3	DBR71210	Manual Solution	42.77	171.08
34	NMOS	ROHM N-Channel MOSFET	M1_HVR1, M1_HVR2, M1_HVR3, M1_HVR4, U14_HVR1, U14_HVR2, U14_HVR3, U14_HVR4, U15_HVR1, U15_HVR2, U15_HVR3, U15_HVR4	12		Digi-Key	2SK3019TLCT-ND	Rohm	2SK3019-TL	Manual Solution	0.415	4.98
35	BNC	BNC Straight Away Connector	P1, P2, P4-P11	10		Digi-Key	ARF1687-ND	Amphenol RF	031-5329-51RFX	Manual Solution	2.4	24
36	Header 10X2	Header, 10-Pin, Dual row	P3	1		Digi-Key	1175-1612-ND	CNC Tech	3020-20-0100-00	Manual Solution	0.73	0.73
37	Header 6H	Header, 6-Pin, Right Angle	P12	1		Digi-Key	WM5236-ND	Molex	0026615030	Manual Solution	1.77	1.77
38	Panel Mount SHV Cable Assembly (SHV Jack to BNC)	Panel Mount SHV Cable Assembly (SHV Jack to BNC)	Part1	1								
39	Pins for female molex connector	Pins for female molex connector	Part2	1		Digi-Key	WM2307-ND	Molex	0008580126	Manual Solution	1.02	1.02
40	Mating 6 pin molex connector	Mating 6 pin molex connector	Part3	1		Digi-Key	WM2126-ND	Molex	0009508061	Manual Solution	0.35	0.35
41	33	Resistor	R1, R46-R49, R56_QS1, R56_QS2, R57_HVR1, R57_HVR2, R57_HVR3, R57_HVR4, R63_HVR1, R63_HVR2, R63_HVR3, R63_HVR4	15	33	Digi-Key	RHM33ICT-ND	Rohm	ESR18EZPJ330	Manual Solution	0.146	2.19
42	22K	Resistor	R2	1	22k	Digi-Key	P22KBCCT-ND	Panasonic	ERA-8AEB223V	Manual Solution	0.66	0.66
43	3.01K	Resistor	R3_DR1, R3_DR2, R3_DR3, R3_DR4, R5_DR1, R5_DR2, R5_DR3, R5_DR4, R11_DR1, R11_DR2, R11_DR3, R11_DR4, R13_DR1, R13_DR2, R13_DR3, R13_DR4, R66_FDR1, R66_FDR2, R72_FDR1, R72_FDR2	20	3.01K	Digi-Key	P3.01KBCCT-ND	Panasonic	ERA-8AEB3011V	Manual Solution	0.492	9.84
44	100K OHM	Resistor	R4_DR1, R4_DR2, R4_DR3, R4_DR4, R12_DR1, R12_DR2, R12_DR3, R12_DR4	8	100K OHM	Digi-Key	P100KBCCT-ND	Panasonic	ERA-8AEB104V	Manual Solution	0.474	4.74
45	1k	Resistor	R6_DR1, R6_DR2, R6_DR3, R6_DR4, R9_DR1, R9_DR2, R9_DR3, R9_DR4	8	1k	Digi-Key	P1.0KBCCT-ND	Panasonic	ERA-8AEB102V	Manual Solution	0.474	4.74
46	0 ohm	Resistor	R7_DR1, R7_DR2, R7_DR3, R7_DR4, R10_DR1, R10_DR2, R10_DR3, R10_DR4	8	0 ohm	Digi-Key	P0.0ECT-ND	Panasonic	ERJ-8GEY0R00V	Manual Solution	0.072	0.72
47	OMIT	Resistor	R8_DR1, R8_DR2, R8_DR3, R8_DR4, R69_FDR1, R69_FDR2	6	OMIT							
48	1k	Resistor	R14_PZ1, R14_PZ2, R14_PZ3, R14_PZ4, R15_PZ1, R15_PZ2, R15_PZ3, R15_PZ4	8	1k	Digi-Key	P1.0KBCCT-ND	Panasonic	ERA-8AEB102V	Manual Solution	0.474	4.74
59	15k	Resistor	R16_PZ1, R16_PZ2, R16_PZ3, R16_PZ4, R25_PZ1, R25_PZ2, R25_PZ3, R25_PZ4, R28_HPF1, R28_HPF2, R32_HPF1, R32_HPF2, R38_MA1, R38_MA2, R38_MA3, R38_MA4	16	15k, [NoParam]	Digi-Key	YAG5034CT-ND	Yageo	RT1206BRD0715KL	Manual Solution	0.417	6.67
50	3.24k	Resistor	R17_PZ1, R17_PZ2, R17_PZ3, R17_PZ4, R18_PZ1, R18_PZ2, R18_PZ3, R18_PZ4	8	3.24k	Digi-Key	P3.24KBCCT-ND	Panasonic	ERA-8AEB3241V	Manual Solution	0.474	4.74
51	4.99k	Resistor	R19_PZ1, R19_PZ2, R19_PZ3, R19_PZ4, R26_PZ1, R26_PZ2, R26_PZ3, R26_PZ4, R30_HPF1, R30_HPF2, R33_HPF1, R33_HPF2	12	4.99k	Digi-Key	P4.99KBCCT-ND	Panasonic	ERA-8AEB4991V	Manual Solution	0.474	5.69
52	18.7k	Resistor	R20_PZ1, R20_PZ2, R20_PZ3, R20_PZ4, R21_PZ1, R21_PZ2, R21_PZ3, R21_PZ4, R22_PZ1, R22_PZ2, R22_PZ3, R22_PZ4, R23_PZ1, R23_PZ2, R23_PZ3, R23_PZ4, R24_PZ1, R24_PZ2, R24_PZ3, R24_PZ4	20	18.7k	Digi-Key	P18.7KBCCT-ND	Panasonic	ERA-8AEB1872V	Manual Solution	0.474	9.48
53	20K	Resistor	R27_PZ1, R27_PZ2, R27_PZ3, R27_PZ4, R61_HVR1, R61_HVR2, R61_HVR3, R61_HVR4, R62_HVR1, R62_HVR2, R62_HVR3, R62_HVR4, R64_HVR1, R64_HVR2, R64_HVR3, R64_HVR4	16	20K, [NoParam]			Panasonic	ERJ-8ENF2002V	Manual Solution		
54	1.13K		R29_HPF1, R29_HPF2	2		Digi-Key	P1.13KBCCT-ND	Panasonic	ERA-8AEB1131V	Manual Solution	0.64	1.28
55	2.26K		R31_HPF1, R31_HPF2	2		Digi-Key	P2.26KBCCT-ND	Panasonic	ERA-8AEB2261V	Manual Solution	0.64	1.28
56	30K, 10W		R34, R35	2		Digi-Key	20J30KE-ND	Ohmite	20J30KE	Manual Solution	4.03	8.06
57	10k, 3W		R36, R58_HVR1, R58_HVR2, R58_HVR3, R58_HVR4	5		Digi-Key	ALSR3F-10.0K-ND	Vishay Dale	ALSR0310K00FE12	Manual Solution	1.83	9.15
58	1k		R37_MA1, R37_MA2, R37_MA3, R37_MA4, R50_OS1, R50_OS2, R50_OS3, R50_OS4	8	1k	Digi-Key	P1.0KBCCT-ND	Panasonic	ERA-8AEB102V	Manual Solution	0.474	4.74
49	4.99K	Resistor	R39_MA1, R39_MA2, R39_MA3, R39_MA4, R40_DD1, R40_DD2, R40_DD3, R40_DD4, R41_DD1, R41_DD2, R41_DD3, R41_DD4, R43_DD1, R43_DD2, R43_DD3, R43_DD4, R44_DD1, R44_DD2, R44_DD3, R44_DD4	20	4.99k, [NoParam]			Vishay Dale	TNPW12064K99BEEA	Manual Solution		
60	0 ohm	Resistor	R42_DD1, R42_DD2, R42_DD3, R42_DD4	4	0 ohm	Digi-Key	P0.0ECT-ND	Panasonic	ERJ-8GEY0R00V	Manual Solution	0.1	0.4
61	0 Ohm	Resistor	R45_DD1, R45_DD2, R45_DD3, R45_DD4	4		Digi-Key	P0.0ECT-ND	Panasonic	ERJ-8GEY0R00V	Manual Solution	0.1	0.4
62	49.9		R51_OS1, R51_OS2, R51_OS3, R51_OS4	4		Digi-Key	P49.9BCCT-ND	Panasonic	ERA-8AEB49R9V	Manual Solution	0.66	2.64
63	49.9	Thin film resistor	R52_OS1, R52_OS2, R52_OS3, R52_OS4, R53_OS1, R53_OS2, R53_OS3, R53_OS4, R54_OS1, R54_OS2, R54_OS3, R54_OS4, R55_OS1, R55_OS2, R55_OS3, R55_OS4	16		Digi-Key	P49.9BCCT-ND	Panasonic	ERA-8AEB49R9V	Manual Solution	0.474	7.58
64	10K	Resistor	R59_HVR1, R59_HVR2, R59_HVR3, R59_HVR4	4	10K	Digi-Key	P10.0KFCT-ND	Panasonic	ERJ-8ENF1002V	Manual Solution	0.11	0.44
65	200K	Resistor	R60_HVR1, R60_HVR2, R60_HVR3, R60_HVR4	4		Digi-Key	P200KFCT-ND	Panasonic	ERJ-8ENF2003V	Manual Solution	0.11	0.44
66	3.01K OHM	Resistor	R65_FDR1, R65_FDR2, R73_FDR1, R73_FDR2	4	3.01K	Digi-Key	P3.01KBCCT-ND	Panasonic	ERA-8AEB3011V	Manual Solution	0.69	2.76
67	100K OHM	Resistor	R67_FDR1, R67_FDR2, R71_FDR1, R71_FDR2	4	100K	Digi-Key	P100KBCCT-ND	Panasonic	ERA-8AEB104V	Manual Solution	0.66	2.64
68	1K	Resistor	R68_FDR1, R68_FDR2, R70_FDR1, R70_FDR2, R74_FDR1, R74_FDR2	6	1K	Digi-Key	P1.0KBCCT-ND	Panasonic	ERA-8AEB102V	Manual Solution	0.66	3.96
69	0.4W	Resistor	R77, R78	2	1K	Digi-Key	TNP1.00KACCT-ND	Vishay Dale	TNPW12061K00BEEA	Manual Solution	0.72	1.44
	9.31k	Resistor	R79, R80	2	9.31k	Digi-Key	P93.1KBCCT-ND	Panasonic	ERA-8AEB9312V	Manual Solution	0.66	1.32
71	TESTPT	PCB Testpoint	TP1-TP3, TP6, TP12, TP13, TP18, TP19, TP23, TP25, TP27, TP31, TP34, TP36, TP43, TP45, TP48, TP51, TP70-TP78	27		Digi-Key	36-5016CT-ND	Keystone Electronics	5016	Manual Solution	0.3348	9.04
72	LT1125CS	Quad Low Noise, High-Speed Precision Operational Amplifier	U1_DR1, U1_DR2, U1_DR3, U1_DR4	4	LT1125CS	Digi-Key	LT1125CSW#PBF-ND	Analog Devices / Linear Technology	LT1125CSW#PBF	Manual Solution	12.71	50.84
73	MAX4659	SPDT CMOS Switch, 25 ohms Ron	U2_PZ1, U2_PZ2, U2_PZ3, U2_PZ4, U3_PZ1, U3_PZ2, U3_PZ3, U3_PZ4	8	MAX4659EUA+	Digi-Key	MAX4659EUA+-ND	Maxim	MAX4659EUA+	Manual Solution	3.95	31.6
74	OP27GSZ	Ultra-Low Noise, Precision Operational Amplifier	U4_PZ1, U4_PZ2, U4_PZ3, U4_PZ4, U6_PZ1, U6_PZ2, U6_PZ3, U6_PZ4, U7_PZ1, U7_PZ2, U7_PZ3, U7_PZ4, U11_MA1, U11_MA2, U11_MA3, U11_MA4	16		Digi-Key	OP27GSZ-ND	Analog Devices	OP27GSZ	Manual Solution	3.58	57.28
75	ADA4700-1	High Voltage Opamp	U5_PZ1, U5_PZ2, U5_PZ3, U5_PZ4, U10_HPF1, U10_HPF2	6		Digi-Key	ADA4700-1ARDZ-ND	Analog Devices	ADA4700-1ARDZ	Manual Solution	6.69	40.14
76	AD829JR	High-Speed, Low-Noise Video Operational Amplifier	U8_HPF1, U8_HPF2, U9_HPF1, U9_HPF2	4		Digi-Key	AD829ARZ-ND	Analog Devices	AD829ARZ	Manual Solution	6.38	25.52
77	AD8672	High-Speed, Low-Power Dual Operational Amplifier	U12_DD1, U12_DD2, U12_DD3, U12_DD4	4		Arrow	AD8672ARZ	Analog Devices	AD8672ARZ	Manual Solution	3.37	13.48
78	OP467	Quad Low Noise, High-Speed Precision Operational Amplifier	U16_FDR1, U16_FDR2	2	OP467GSZ	Digi-Key	OP467GSZ-ND	Analog Devices	OP467GSZ	Manual Solution	16.3	32.6