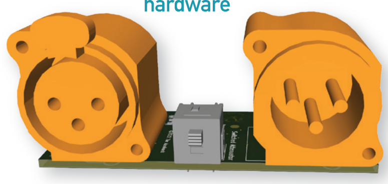
Signal Limiter With Switched Attenuator (XLR3 Connectors)

Requirements:

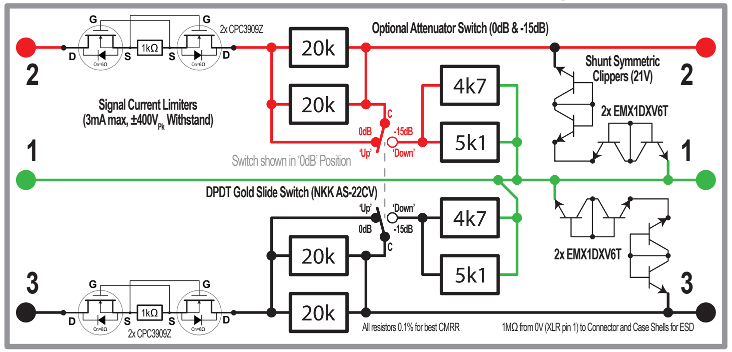
- ±400V Input Protection PCBs
- 15dB attenuation from low-z input into 200kΩ output load
- XLR through connections (ie 'barrel' equivalent)
- Signal path run as precisely balanced differential-pair for signal integrity and high CMRR
- Provide self-resetting signal input protection per leg
- Negligible effect on signal integrity (good for 24+ bit ENOB with high-z load, adds ~1kΩ resistance per leg)
- Use cheap and readily available parts, no power supply
- Small cheap in-line PCB with SMD electronic components only
- Zero alignment or AOT required

open source hardware



Arrangement of Connectors, PCB & Attenuator Switch

Input: XLR-3 Female | Output: XLR-3 Male

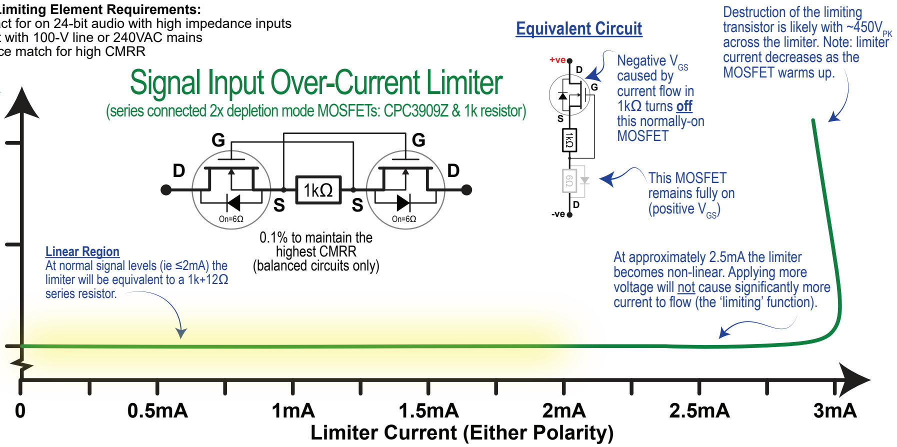


Indicative Rendering Showing Customization (not to scale)

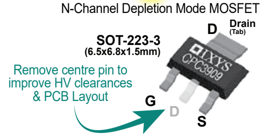
YONGU L02A 110-65-45 Silver Case

Series Current Limiting Element (2x CPC3909Z & 1k) Performance Summary = 'Adds ~1kΩ per leg, otherwise ideal'

Series Current Limiting Element Requirements:
- Negligible impact for on 24-bit audio with high impedance inputs
- Survive contact with 100-V line or 240VAC mains
- Good impedance match for high CMRR



CPC3909Z (SOT223-3)
N-Channel Depletion Mode MOSFET



Absolute Maximum Ratings @ 25ºC

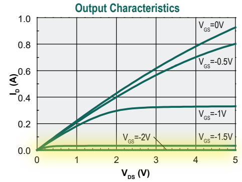
Parameter	Ratings	Units
Drain-to-Source Voltage ($V_{(BR)DSX}$)	400	V
Gate-to-Source Voltage (V_{GS})	15	V
Total Package Dissipation [1]		W
SOT-89	1.1	W
SOT-223	2.5	W
Operational Temperature	-40 to +110	ºC
Storage Temperature	-40 to +125	ºC

[1] Mounted on 1"x1" FR4 board.

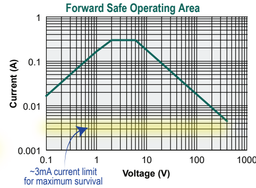
Electrical Characteristics @25ºC (Unless Otherwise Specified)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Gate-to-Source Off Voltage	$V_{GS(off)}$	I_D=1 µA, V_{DS}=5V	-1.4	-	-3.1	V
Drain-to-Source Leakage Current	$I_{DS(off)}$	V_{GS}= -5.5V, V_{DS}=240V	-	-	20	nA
		V_{GS}= -5.5V, V_{DS}=400V	-	-	1	µA
Drain Current	I_D	V_{GS}= 0V, V_{DS}=5V	300	-	-	mA
On-Resistance	$R_{DS(on)}$	V_{GS}= 0V, I_{DS}=300mA	-	4.5	6	Ω
Gate Leakage Current	I_{GSS}	V_{GS}=15V	-	-	100	nA
Gate Capacitance	C_{ISS}	V_{DS}= V_{GS}=0V	-	-	275	pF

Output Characteristics



Forward Safe Operating Area



Switched Attenuator Components Selection:

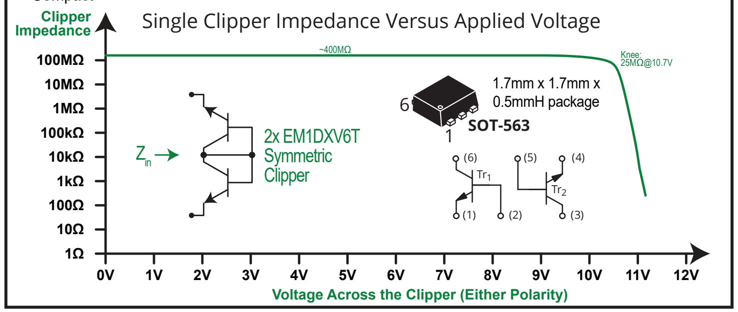
Refer to the SMath calculation sheet:

Attenuator Calculator with Tolerances A3 20220601.sm

- **Needed input for attenuator design:**
  - The target analyzer's differential input impedance: ie **LoadR:≈?kΩ** (input impedance between pins 2 and 3). Worked example: 100kΩ.
  - The target analyzer's differential maximum expected (ie 'full scale') signal voltage (RMS voltage between pins 2 and 3): , ie **Vin_{RMS}:≈?V** Worked example: $25V_{RMS}$.
  - The maximum expected signal voltage $Vmax_{RMS}$:≈?V Worked example: $125V_{RMS}$.
  - The attenuation target: **Atten:≈?dB** This is the ratio between the maximum signal voltage to be measured and the maximum measurable input voltage of the analyzer. When the attenuator matches these, it makes available the analyzer's maximum dynamic range. The attenuator also boosts the dynamic range when measuring noise so a nice round-number of dB is convenient. Given: $20x \log_{10}\left(\frac{25V}{125V}\right) = -13.98$ dB atten chosen for the worked example: 15dB.
- **Select number of shunt clippers:**
  Worked example: given $25V_{RMS}$ differential is $\pm17.7V_{Pk}$ on each leg (referenced to 0V) we will need two shunt clippers in series (each passes $\sim9V_{Pk}$).
- **Resistor selection:**
  - Download the awesome and free SMath if you don't already have it: https://en.smath.com.
  - Enter the shunt and series resistor values to get the required attenuation, & check series resistor power dissipation is OK.
  - Use 0.1% resistors to maximise CMRR and optimise for available values (noting that the accuracy of the absolute division ratio is not particularly important).

Shunt Voltage Clipper Protection Element: (2x EMX1DXV6T NPN BJT) Performance Summary = 'Adds ~5pF, otherwise ideal'

Shunt Voltage Limiting Element Requirements:
- Negligible impact for on 24-bit audio up to 18V (0V pin-1 referenced) so two are required per leg
- Hard ~21V 'knee', sink ~5mA current continuously
- Low capacitance
- Compact



EMX1DXV6T MAXIMUM RATINGS (T_A = 25°C)

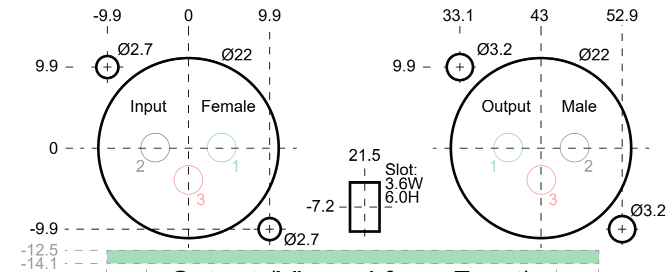
Rating	Symbol	Value	Unit
Collector-Base Voltage	$V_{(BR)CBO}$	60	Vdc
Collector-Emitter Voltage	$V_{(BR)CEO}$	50	Vdc
Emitter-Base Voltage	$V_{(BR)EBO}$	7.0	Vdc
Collector Current − Continuous	I_C	100	mAdc

THERMAL CHARACTERISTICS

Characteristic (One Junction Heated)	Symbol	Max	Unit
Total Device Dissipation T_A = 25°C Derate above 25°C	P_D	357 (Note 1) 2.9 (Note 1)	mW mW/°C
Thermal Resistance − Junction-to-Ambient	$R_{\theta JA}$	350 (Note 1)	°C/W
Characteristic (Both Junctions Heated)	**Symbol**	**Max**	**Unit**
Total Device Dissipation T_A = 25°C Derate above 25°C	P_D	500 (Note 1) 4.0 (Note 1)	mW mW/°C
Thermal Resistance − Junction-to-Ambient	$R_{\theta JA}$	250 (Note 1)	°C/W
Junction and Storage Temperature Range	T_J, T_{stg}	−55 to +150	°C

EMX1DXV6T ELECTRICAL CHARACTERISTICS (T_A = 25°C)

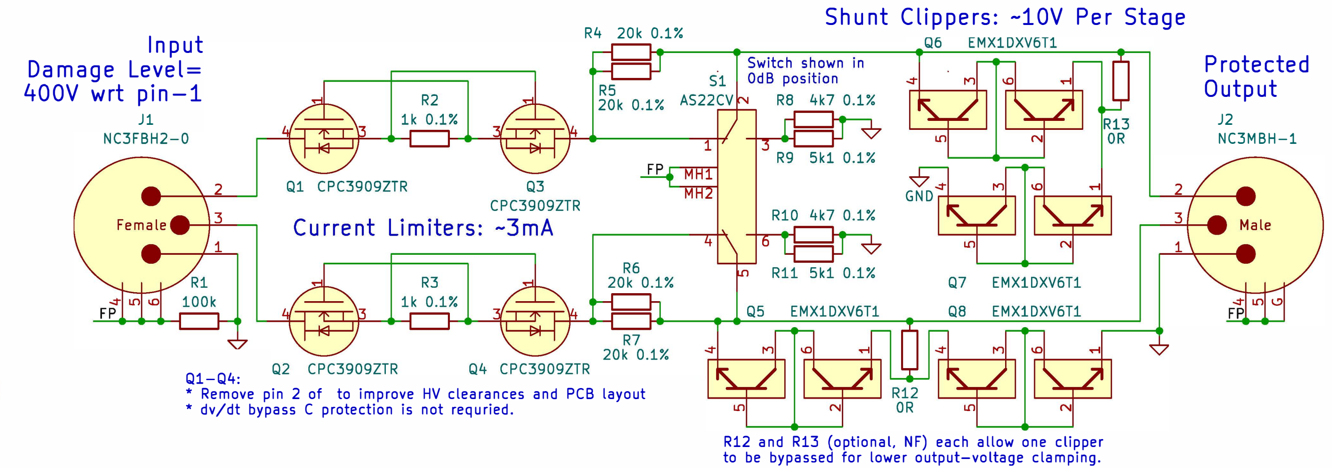
Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 50 µAdc, I_E = 0)	$V_{(BR)CBO}$	60	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	$V_{(BR)CEO}$	50	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 50 µAdc, I_E = 0)	$V_{(BR)EBO}$	7.0	–	–	Vdc
Collector-Base Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	I_{CBO}	–	–	0.5	µA
Emitter-Base Cutoff Current (V_{EB} = 7.0 Vdc, I_B = 0)	I_{EBO}	–	–	0.5	µA
Collector-Emitter Saturation Voltage (Note 2) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	–	–	0.4	Vdc
DC Current Gain (Note 3) (V_{CE} = 6.0 Vdc, I_C = 1.0 mAdc)	h_{FE}	120	–	560	–
Transition Frequency (V_{CE} = 12 Vdc, I_C = 2.0 mAdc, f = 30 MHz)	f_T	–	180	–	MHz
Output Capacitance (V_{CB} = 12 Vdc, I_C = 0 Adc, f = 1 MHz)	C_{OB}	–	2.0	–	pF



Cutout (Viewed from Front)
(depth behind panel: 30mm)

20220601 Differential Limiter Attenuator.ai

Example: Audio Analyzer Input
FS=25VRMS, Zin=200k (differential),
Attenuation Chosen = 0dB & 15dB (FS for 100V-Line)



H1 MountingHole
H2 MountingHole
FID1 Fiducial
FID2 Fiducial
FID3 Fiducial
FID4 Fiducial

Kicad Project, SCH & PCB are attached to this PDF.
Access via the attachments panel.

Aardvark Acoustics

Sheet: /

File: Attenuator Differential Open Source.kicad_sch

Title: SA1 Example Limiter Attenuator

Size: A5	Date: 1/6/2022	**Rev: V1.3**
KiCad E.D.A. kicad (6.0.2)		Id: 1/1

Resistive Attenuator Calculator

Inputs:

$Z_{in} := 200\ k\Omega$ — *Expected differential input impedance of the analyzer*

Series Resistors:

$InputR := 1010.5\ \Omega$ — $InputR_{tol} := \pm 0.5\ \%$

$R1A := 20\ k\Omega$ — $R1A_{tol} := \pm 0.2\ \%$

$R1B := 20\ k\Omega$ — $R1B_{tol} := \pm 0.2\ \%$

Shunt Resistors:

$R2A := 4.7\ k\Omega$ — $R2A_{tol} := \pm 0.2\ \%$

$R2B := 5.1\ k\Omega$ — $R2B_{tol} := \pm 0.2\ \%$

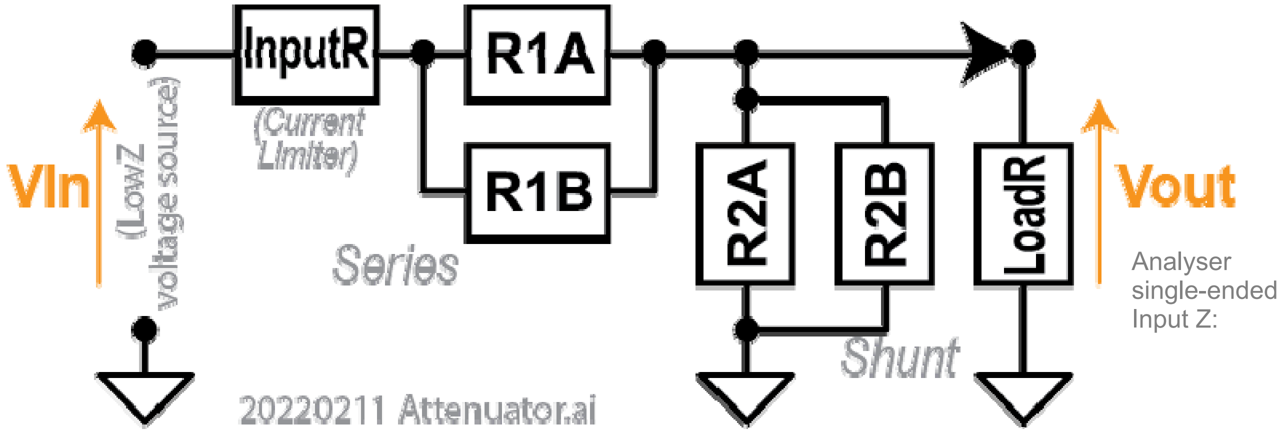
$LoadR := \frac{Z_{in}}{2}$ — Analyser single-ended Input Z:

Note that the resistors can, with very low probability, be ouside of their tolerance values. It is recommended to double the rated tolerance for a 2x safety margin.

Current Limit:

$I_{Limit} := 5\ mA$ — *Limiter maximum current (mA). Specify an excess (for safety margin)*

Expected InputR: $1008 - 1013\ \Omega$



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Calculated Intermediate Values:

Resistances:

$R1A_{range} := \left(R1A + \left(R1A \cdot R1A_{tol}\right)\right)$

$R1A_{min} := \mathrm{Min}\left(R1A_{range}\right) = 19.96\ k\Omega$

$R1A_{max} := \mathrm{Max}\left(R1A_{range}\right) = 20.04\ k\Omega$

$R1B_{range} := \left(R1B + \left(R1B \cdot R1B_{tol}\right)\right)$

$R1B_{min} := \mathrm{Min}\left(R1B_{range}\right) = 19.96\ k\Omega$

$R1B_{max} := \mathrm{Max}\left(R1B_{range}\right) = 20.04\ k\Omega$

$R2A_{range} := \left(R2A + \left(R2A \cdot R2A_{tol}\right)\right)$

$R2A_{min} := \mathrm{Min}\left(R2A_{range}\right) = 4.6906\ k\Omega$

$R2A_{max} := \mathrm{Max}\left(R2A_{range}\right) = 4.7094\ k\Omega$

$R2B_{range} := \left(R2B + \left(R2B \cdot R2B_{tol}\right)\right)$

$R2B_{min} := \mathrm{Min}\left(R2B_{range}\right) = 5.0898\ k\Omega$

$R2B_{max} := \mathrm{Max}\left(R2B_{range}\right) = 5.1102\ k\Omega$

$InputR_{range} := \left(InputR + \left(InputR \cdot InputR_{tol}\right)\right)$

$InputR_{min} := \mathrm{Min}\left(InputR_{range}\right) = 1005.45\ \Omega$

$InputR_{max} := \mathrm{Max}\left(InputR_{range}\right) = 1015.55\ \Omega$

Series Resistor Combination:

$Series := \frac{R1A \cdot R1B}{(R1A + R1B)} + InputR$

$Series = 11.0105\ k\Omega$ Ideal

$Series_{min} := \frac{R1A_{min} \cdot R1B_{min}}{\left(R1A_{min} + R1B_{min}\right)} + InputR_{min}$

$Series_{min} = 10.9854\ k\Omega$ Min

$Series_{max} := \frac{R1A_{max} \cdot R1B_{max}}{\left(R1A_{max} + R1B_{max}\right)} + InputR_{max}$

$Series_{max} = 11.0356\ k\Omega$ Max

Shunt Resistor Combination:

$Shunt := \frac{1}{\left(\frac{1}{R2A} + \frac{1}{R2B} + \frac{1}{LoadR}\right)}$

$Shunt = 2.3875\ k\Omega$ Ideal

$Shunt_{min} := \frac{1}{\left(\frac{1}{R2A_{min}} + \frac{1}{R2B_{min}} + \frac{1}{LoadR}\right)}$

$Shunt_{min} = 2.3829\ k\Omega$ Min

$Shunt_{max} := \frac{1}{\left(\frac{1}{R2A_{max}} + \frac{1}{R2B_{max}} + \frac{1}{LoadR}\right)}$

$Shunt_{max} = 2.3922\ k\Omega$ Max

Results (Calculated Attenuation etc):

$Atten := 20 \cdot \log_{10}\left(\frac{Shunt}{(Series + Shunt)}\right)$

$Atten = -14.98$ dB Ideal

$Atten_{min} := 20 \cdot \log_{10}\left(\frac{Shunt_{max}}{\left(Series_{min} + Shunt_{max}\right)}\right)$

$Atten_{min} = -14.95$ dB Min

$Atten_{max} := 20 \cdot \log_{10}\left(\frac{Shunt_{min}}{\left(Series_{max} + Shunt_{min}\right)}\right)$

$Atten_{max} = -15.01$ dB Min

Calculated Input Resistance (nominal, for loading):

$Rin := Series + Shunt$

$Rin = 13.4\ k\Omega$ Ideal

Worst Case Series Resistor Power Dissipations:

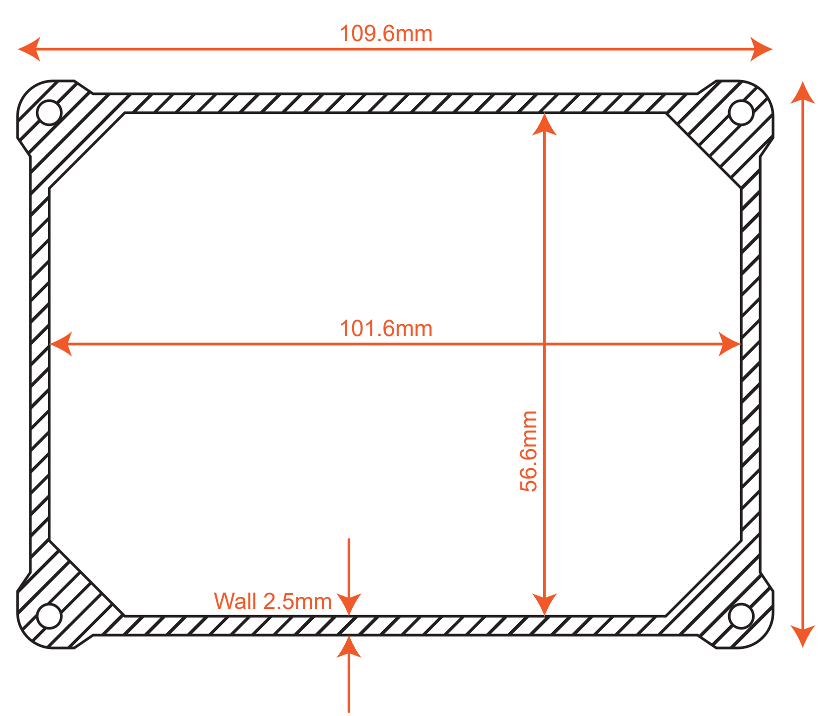
$SeriesForcingV := I_{Limit} \cdot (Series - InputR) = 50\ V$

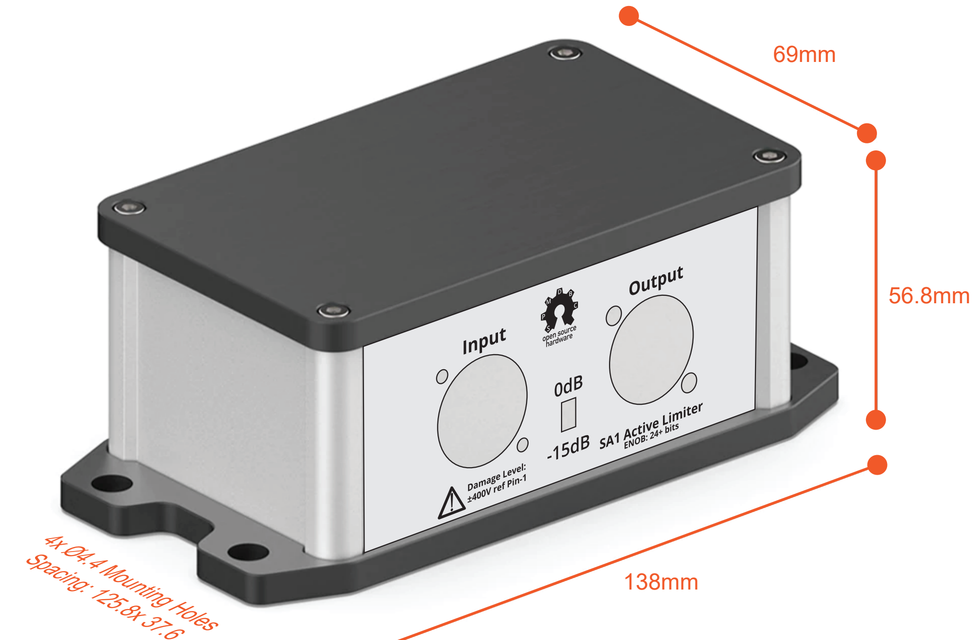
$PD_{R1A} := \frac{SeriesForcingV^2}{R1A_{min}}$ — $PD_{R1A} = 0.13\ W$ — Attenuator resistor max dissipation (0603 = 0.125W, considerably more at 25°C)

$PD_{R1B} := \frac{SeriesForcingV^2}{R1B_{min}}$ — $PD_{R1B} = 0.13\ W$ — Attenuator resistor max dissipation (0603 = 0.125W, considerably more at 25°C)

This SMath worksheet is attached to this PDF (via the attachments panel)

20220601 Attenuator Calculator with Tolerances A3.sm
Refer 1-page design: 20220601 Differential Limiter Attenuator.pdf





Indicative Rendering Showing Customization
(not to scale)

20220601 Enclosure.ai

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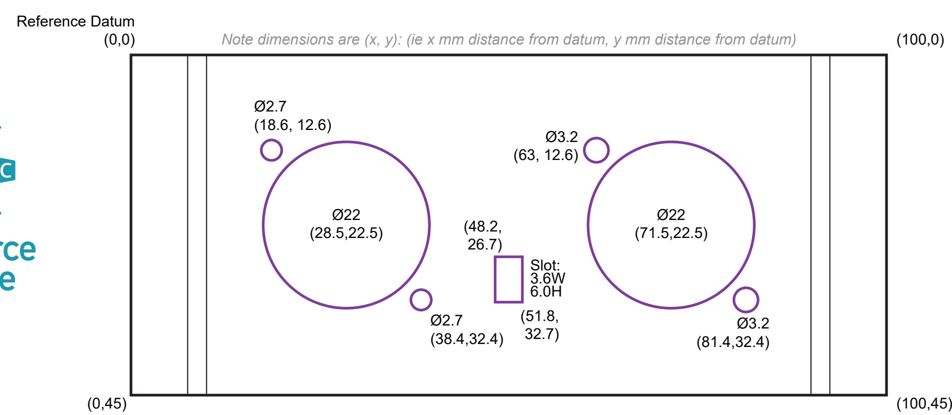
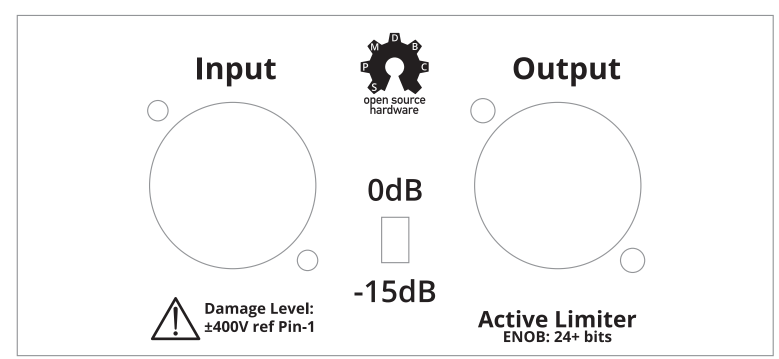
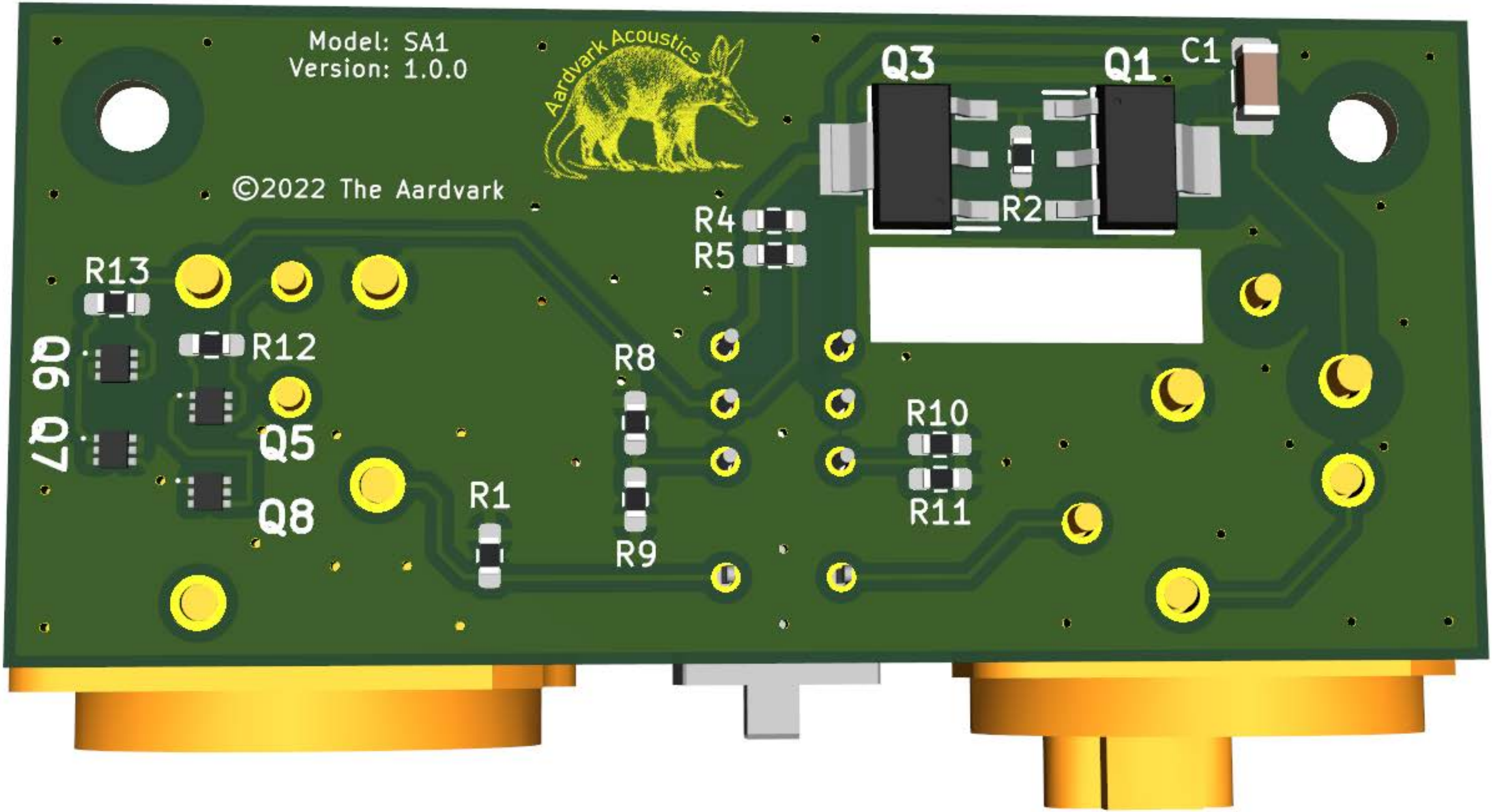


Side Elevation: Customization Cut Lines Shown in Purple (1:1 scale)



Customization Artwork: Permanent Black on Silver, 1:1 scale

YONGUBOX L Series 110-65-45A Aluminium 6063 Silver Enclosure (Black Aluminium Caps)


Model: SA1
Version: 1.0.0
Aardvark Acoustics
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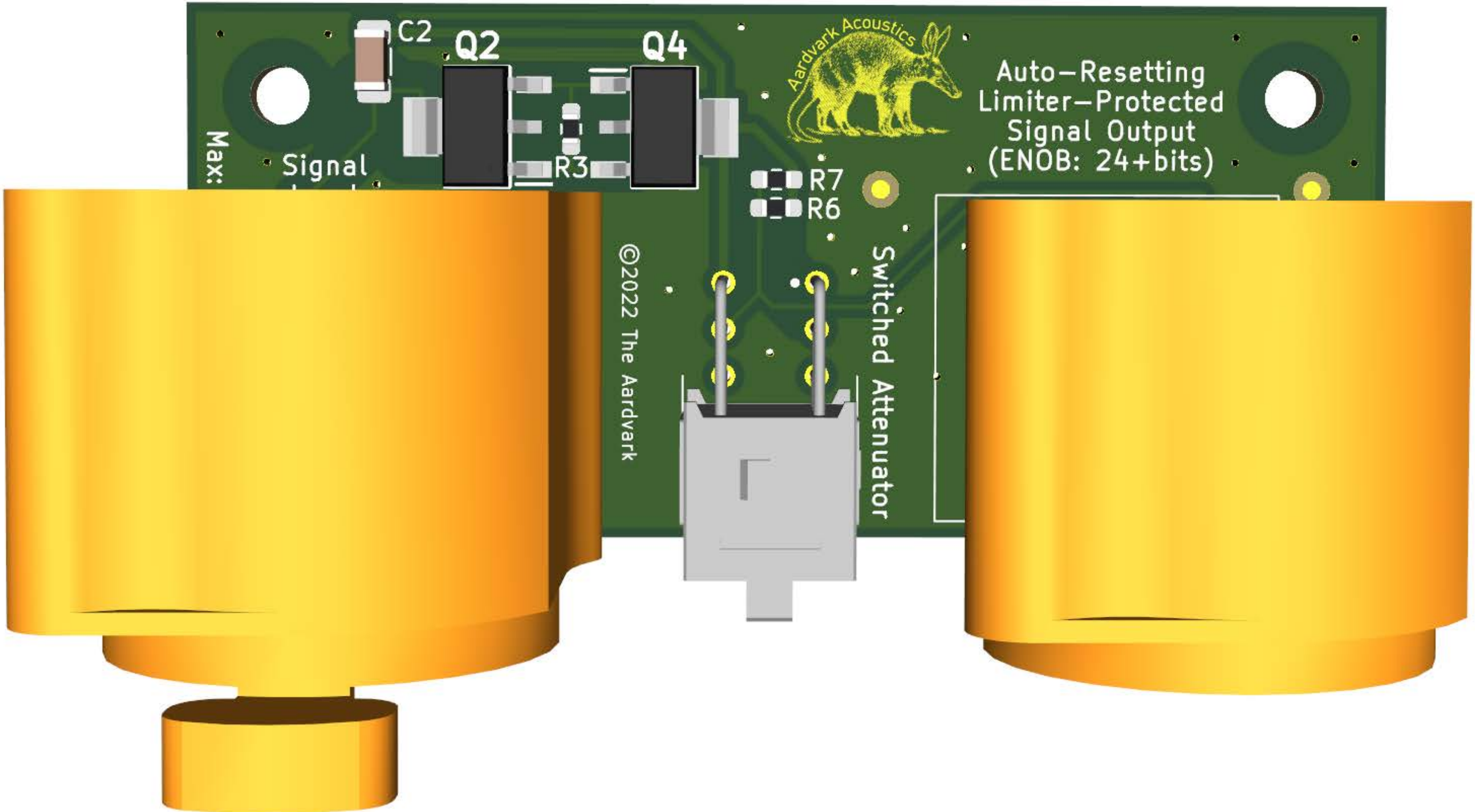
Q3
Q1
C1
R2
R4
R5
R13
R12
Q6
Q7
Q5
Q8
R8
R1
R9
R10
R11


C2
Q2
Q4
R3
R7
R6
Aardvark Acoustics
Auto–Resetting
Limiter–Protected
Signal Output
(ENOB: 24+bits)
Max:
Signal
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Switched Attenuator