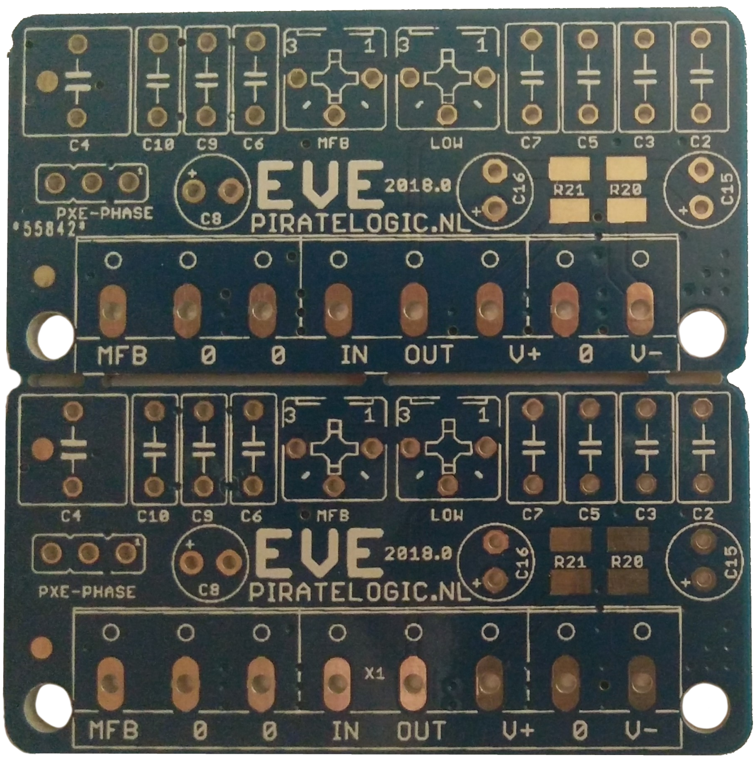
EVE

servo evaluation kit

VERSION 2018.0



SUBJECT TO PERMANENT DEVELOPMENT

Contents

Before you start ....

Thank you for purchasing EVE, prior to assembly please verify the kit contains the below listed parts, incase something is missing or damaged please contact us immediately and please note this manual is subject to permanent development so expect grammar & spell checks, corrections and improvements, **read the ERRATA section before building EVE !!**

Bill of materials

The components valued either **Cx** or **Rx** are **not included in the kit** as they are setup specific as described further in this document.

Qty	Value	Package	Parts
2	10	R1210	R20, R21
2	10-35	E2,5-5	C15, C16
5	1001	R0805D	R1, R2, R3, R11, R19
5	1002	R0805D	R4, R6, R14, R15, R16
1	1003	R0805D	R18
4	100n	C0805	C11, C12, C13, C14
1	1201	R0805D	R7
1	1203	R0805D	R12
1	22-16	E2,5-5	C8
1	2201	R0805D	R8
1	3n3	C0805	C1
2	5K	B25P	LOW, MFB
1	7812	SOT89-3	7812
1	7912	SOT89-3	7912
1	BC849	SOT23	T2
1	BCV62	SOT143B	T1
3	CX	C050-030X075	C6, C9, C10
4	CX	C050-035X075	C2, C3, C5, C7
1	CX	C050-075X075	C4
5	RX	R0805D	R5, R9, R10, R13, R17
1	TL074D	SO14	IC1

Table 1 : The EVE Bom.

Prerequisites

In order to successfully assemble the kit the following prerequisites are needed.

- ESD safe working environment : EVE contains ESD sensitive jFet devices, please adhere to guidelines for safe handling of ESD sensitive components during assembly of the sensors.
- SMD soldering station : the EVE design uses surface mount technology and requires handling and use of an appropriate soldering station to avoid thermal damage to the used parts when soldered onto the PCB.

Warranty / Disclaimer

Although this kit has been developed with lots of love, tenderness and devotion we can only guarantee 100% operation for ready & assembled EVE.

Although EVE has been tested with numerous MFB enclosures it is subject to constant research and development and as such no guarantees and/or warranties can be given for the correct / optimal/failure free working of the module. No responsibility is taken for any damage resulting from the use of this module.

Availability

Bare EVE printed circuit boards without components are available for 25 euro per set of 2 by sending an email to chris*nospam*piratelogic.nl – replace *nospam* with the standard @. An EVE kit containing the PCB and parts excluding Cx and Rx costs 50 euro for a set of 2. Pricing excludes VAT and shipment.

Consultancy

Upon request customised EVE module are available which have been tailored for use with a specific hardware setups. Please contact chris at piratelogic dot nl for more information.

Copyright

The EVE pcb design is a brainchild of Chris Camphuisen and will eventually be released to the public as Open Source Hardware as described in https://en.wikipedia.org/wiki/Open-source_hardware.

MAY THE MUSIC PASSING THROUGH THIS DEVICE

SOMEHOW HELP TO BRING JUST A LITTLE MORE PEACE

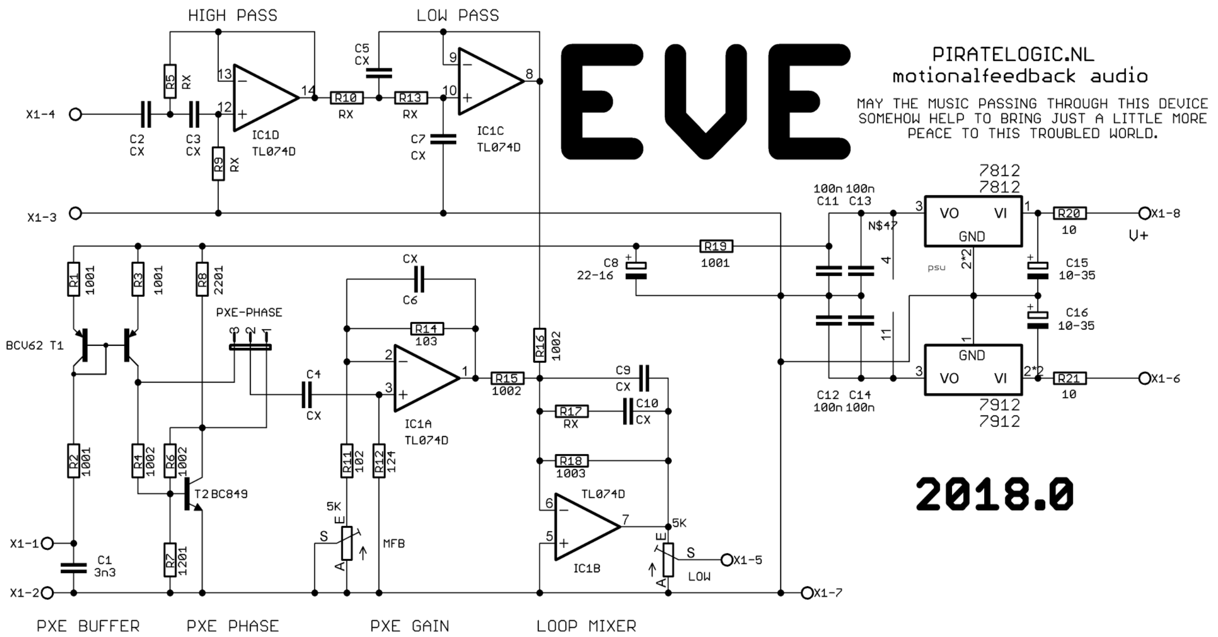
TO THIS TROUBLED WORLD

Introduction

EVE design scope

EVE was originally developed as a quick and dirty solution to add servo bass functionality to an ADAM A7 monitor in conjunction with a StarBass accelerometer equipped woofer. It contains the bare necessities for building a *proof of concept* servoloop and it's small footprint, flexible setup and low cost make it an ideal tool for designing, testing and evaluating servo loops into new and/or existing active setups.

Schematic description



For a larger version of the schematics see page 11, the audio signal at X1-4 enters a second order high pass filter IC1D setting the lower bandwidth pole, the second order lowpass filter IC1C setting the upper bandwidth pole, refer to the ***Crossover points*** section for example filter values. It is advised to feed EVE at X1-4 from a low output impedance to avoid it from negatively affecting the hpf around IC1D.

The StarBass accelerometer signal enters at X1-1 where it is buffered & copied by the current mirror T1 into the phase switch around T2 to allow the usage of third party sensors with different output phase.

The output of the phase switch is amplified by IC1A to match the level of the incoming signal from IC1C, C6 and R14 set the upper pole for the accelerometer signal, C4 and R12 the lower pole, use PXE gain to adjust sensor gain.

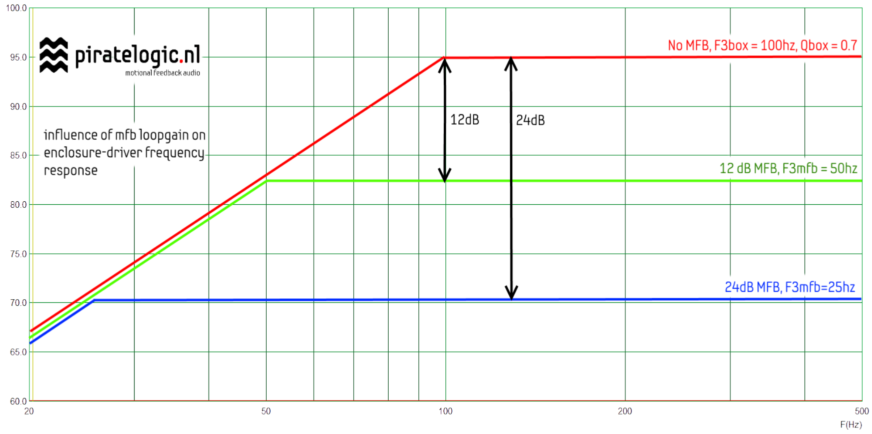
IC1B sums the outputs from IC1C and IC1A, C9 limits the upper bandwidth of the mfb loop, R17 and C10 allow the feedback loop to be shaped to match specific driver / enclosure Q values. The input to the power amplifier is taken from X1-5. 7812 and 7912 are standard voltage regulators to allow EVE from being operated from the power amp rails (max +/- 35V).

Configuring the servo loop

Being designed as a generic mfb correction module EVE supports a wide variety of driver, enclosure and loopgain choices. Because of this generic setup it is not possible to provide a common set of component values, to assist the user with making educated choices the following information is given. **Servo / Motional feedback does not work with Helmholtz resonator based enclosures such as bass reflex boxes.**

Servo loop gain

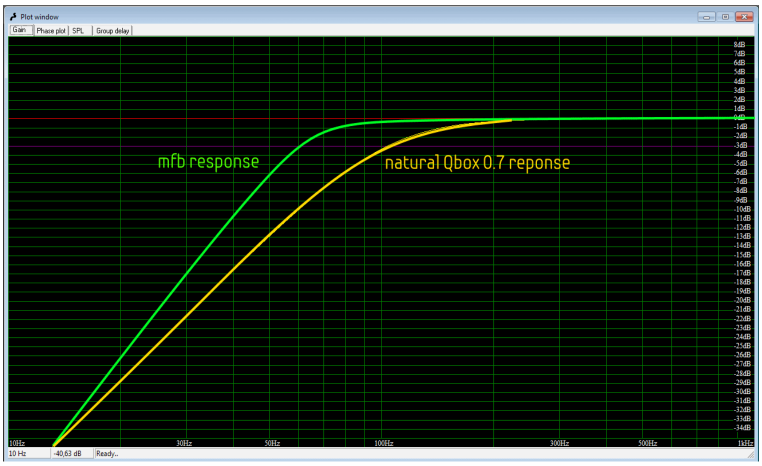
EVE has been designed to offer a theoretical maximum servo loopgain of 20dB, refer to below graph for the relation between servo loopgain and a Q0.7 enclosure frequency response.



Enclosure size, F3mfb, F3box and Qbox

The first step is to choose the lower frequency pole for your mfb box, F3mfb. For the lower limit choose the driver physical resonance frequency Fc, choosing values below Fc will severely limit driver efficiency due to usage outside it's physical limits.

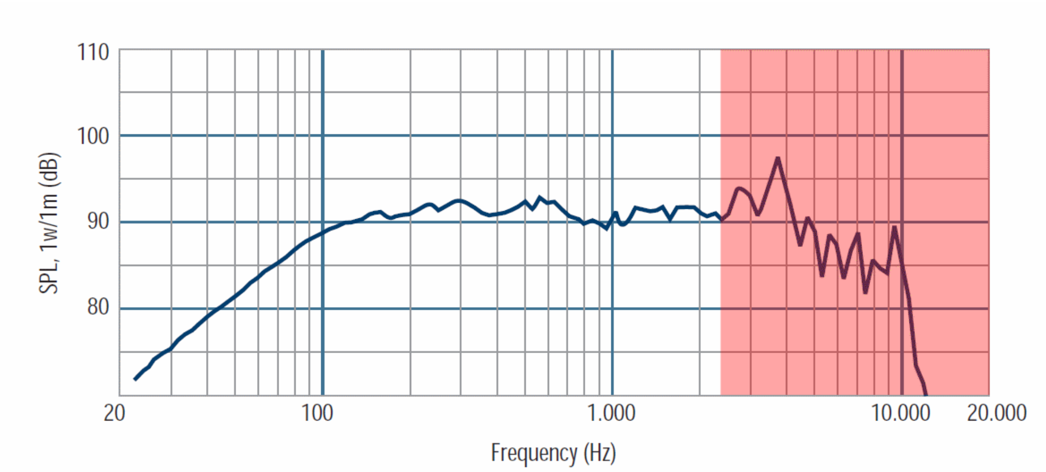
The second step is to choose an enclosure volume using the standard closed box design formulas combined with the driver T&S parameters – to ease down on the involved math one may choose to use a program like WinISD. Start with an enclosure Q of 0.7. As displayed above 12dB MFB loopgain allows you to split F3box in half so if the desired lower frequency pole of your finished box F3mfb is 60hz the chosen F3box should be 120hz or lower.



Example WINISD *response plot for a driver with a* ***Fc*** *of 60hz mounted in a sealed Q=0.7 enclosure with a natural F****box*** *of 120hz which is moved down to F****mfb*** *of 60hz.*

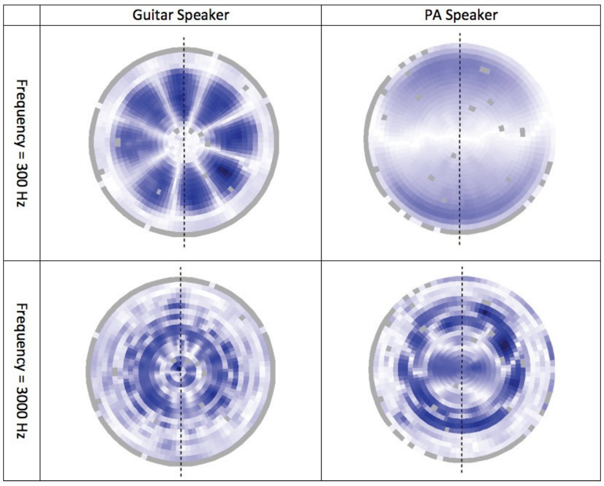
Keep in mind that the higher Q**box** is chosen (= smaller box) the harder the driver will need to work to reach the required excursion, as such one is discouraged from using Q**box** values above 1 as it will severely limit efficiency and SPL.

Low Pass Filter



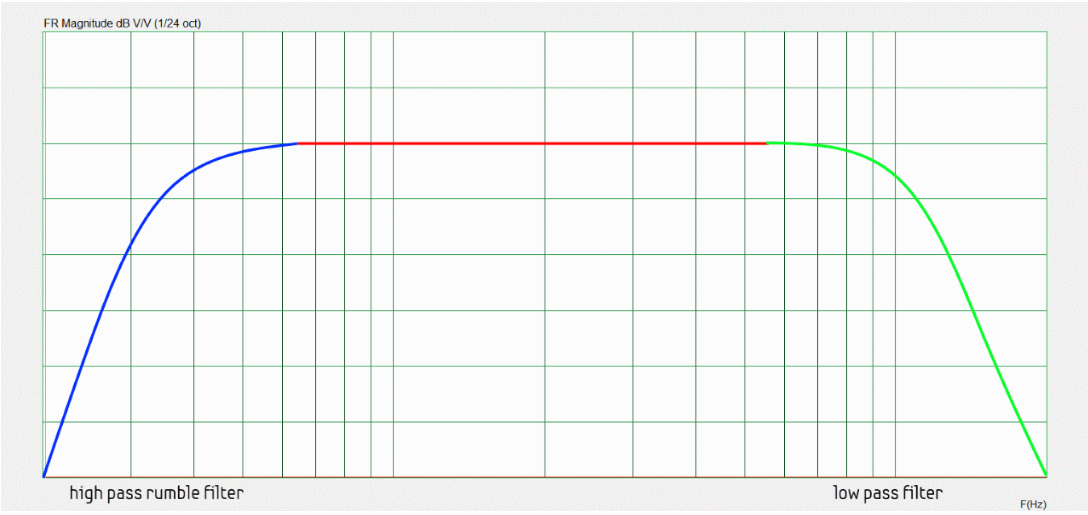
The third step is to decide on a low pass filter frequency - **F1pf** - using the drivers datasheet as reference. EVE's onboard lowpass filter follows a 2nd order Sallen Key setup, as such it is advised to choose F1pf at least 1 octave below the first occurrence of cone breakup. In the example above cone breakup happens in the red region onwards 2500hz making 1250hz or lower a valid choice for **F1pf**

For mfb to work best the driver cone needs to follow the VC movement as a whole uniform body without any partial vibrations like shown for the guitar speaker image (courtesy https://www.premierguitar.com) on the right. The reason for this is that the correction signal originating from the voicecoil mounted accelerometer is only valid / usable for the conearea which follows the VC movement 1:1. Breakup introduces partial distortions which are not 'heard' by the accelerometer and thus not covered by the feedbackloop.



Crossover points

Using F3mfb and F1pf and F3box the component values for the desired crossover points can be calculated. The blue curve represents F3mfb and the green curve F1pf. These values were calculated using http://sim.okawa-denshi.jp/en/OPstool.php for the lowpass and http://sim.okawa-denshi.jp/en/OPseikiHikeisan.htm for the highpass filters.



2nd order Rumble filter IC1D Q=0.5

C2,C3 (nF)	R5, R9 (K)	Frequency (hz)
100	15	106
100	18	88
220	10	72
220	12	60
220	15	48
220	18	40
220	22	32
220	27	27
220	33	21

2nd order Lowpass filter IC1C Q=0.74

R10,R13 (K)	C5 (nF)	C7(nF)	Frequency (hz)	C9 (nF)
2.2	47	100	1055	1n5
3.3	47	100	703	2n2
3.9	47	100	595	2n7
4.7	47	100	493	3n3
2.7	100	220	397	3n9
3.3	100	220	325	4n7
3.9	100	220	275	5n6
4.7	100	220	228	6n8
5.6	100	220	191	8n2

In case the module is to be used with existing active enclosures it's build-in rumble and lowpass filters may need disabling.

- **Disabling the rumble filter** : omit **R5,** use a 220K resistor for **R9** and replace **C2 ,C3** with wire bridges.
- **Disabling the lowpass filter** : omit **C5, C7** and replace **R10, R13** with 0 ohm resistors.

Sensor gain

The fourth step is to configure the MFB preamp IC1A. Acceleration sensor output is determined both by its sensitivity in mV/G as well as the drivers linear cone excursion - to reproduce a certain SPL a small diameter driver will need to perform larger excursions then a large diameter driver, as such the accelerometer output is depended on the driver cone diameter. Longstroke drivers with a high Xmax will typically exhibit a relative high signal output when compared to standard drivers. To accommodate for this ajust **PXE Gain** which sets the gain for the incoming accelerometer signal.

Sensor highpass filter

The lower pole for the accelerometer signal Fpxe.low determines the low end loop stability and should be chosen at least at one tenth of F3mfb, too high values in respect to F3mfb will cause phase shift induced LF oscillations. Starting values for C4 and R12 are 680n and 120K setting Fpxe.low at 2hz.

Sensor lowpass filter

The high pole for the accelerometer signal – Fpxe.high – avoids driver breakup from entering the summation signal at IC1C. As a starting value half the low pass filter frequency F_{lpf} should be used when calculating the C6.

C6	Sensor cut-off frequency
2n2	7200 hz
3n3	4822 hz
3n9	4080 hz
4n7	3386 hz
5n6	2842 hz
6n8	2340 hz
8n2	1940 hz
10n	1591 hz
15n	1061 hz
22n	723 hz
33n	482 hz
47n	338 hz

Loop gain bandwidth

C9 limits the upper bandwidth of the mfb loop and it's value should be set to match the lowpass filter setting for IC1C. Please refer to *2nd order Lowpass filter IC1C* table on page 8 for C9 values.

Loop shaping

To safeguard against loop instabilities use R17 and C10 to compensate for loop phase response below F3box.

Loop phase

Please note EVE introduces a 180 degree phase shift between it's input X1-4 and output X1-5 signals due to the inverting nature of the summation opamp IC1B, for phase neutral operation either switch the polarity of the connected driver of introduce a 180 degree phase shifter between X1-5 and the input of the connected power amplifier, in either case use the pxe-phase jumper to maintain the negative feedback loop.

Building EVE

Power requirements

Please note the V- and V+ power connections on the PCB are incorrectly labelled, see ERRATA @ page 16.

The EVE current draw at +/- 12V is 20mA max. When EVE is used to modify off the shelf active loudspeaker enclosures the preferred way to power EVE is to feed it off existing stabilized opamp rails where EVE supports rails between +/- 12 and 18V.   In-case no stabilized opamp rails exists the onboard 78L12 and 79L12 regulators allow EVE to be powered from a maximum rail voltage of +/- 35V.

Do not use R20 and R21 as voltage droppers as these are only allowed to dissipate 50mW and are used for filtering the incoming power only.

The in the schematic indicated values for the electrolytic capacitors C8, C15 and C16 are **minimum values** and may be increased as space allows.

Choosing Components

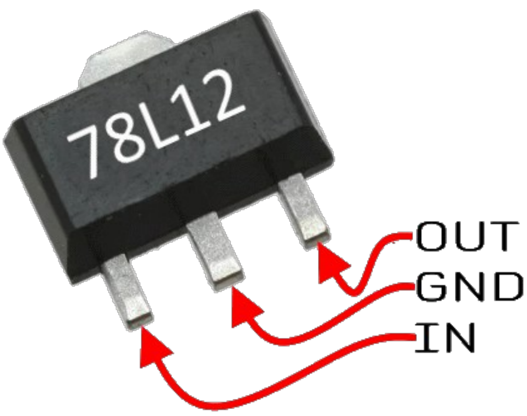
EVE's primary goal is to offer a bare bone *proof of concept* servo loop solution and has been designed with cost effective readily available non-exotic parts in mind. The used TL074 quad dates back to 1978 and by no means represents the state of the art in opamp design. However since servo loops typically operate in the lf domain it's specs are more then sufficient for the task at hand :

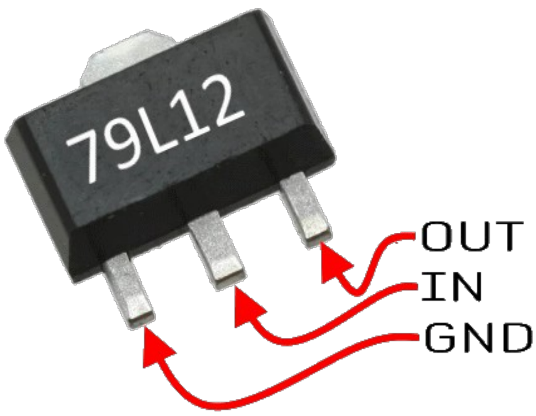
- Low Total Harmonic Distortion: 0.003% (Typical)
- Low Noise Vn = 18 nV/√Hz (Typical) at f = 1 kHz
- High Slew Rate: 13 V/μs (Typical)

Something similar applies to cermet trimmers, 0805 resistors and 5mm pitched Mylar and polypropylene capacitors

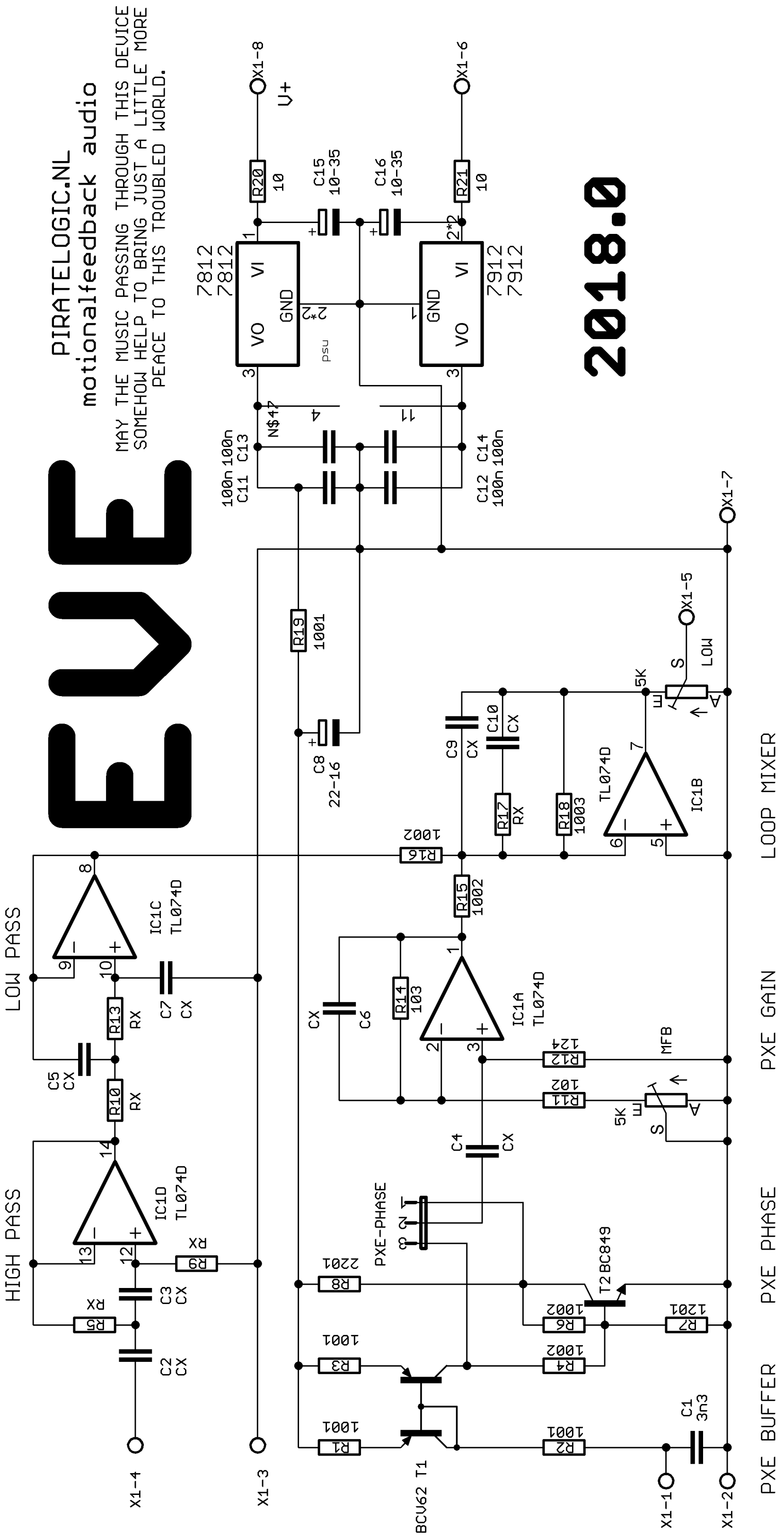
Onboard Regulators

EVE's onboard regulation uses two standard 78L12 and 79L12 regulators in a SOT89 package, before ordering please verify the below indicated pin layouts are used.

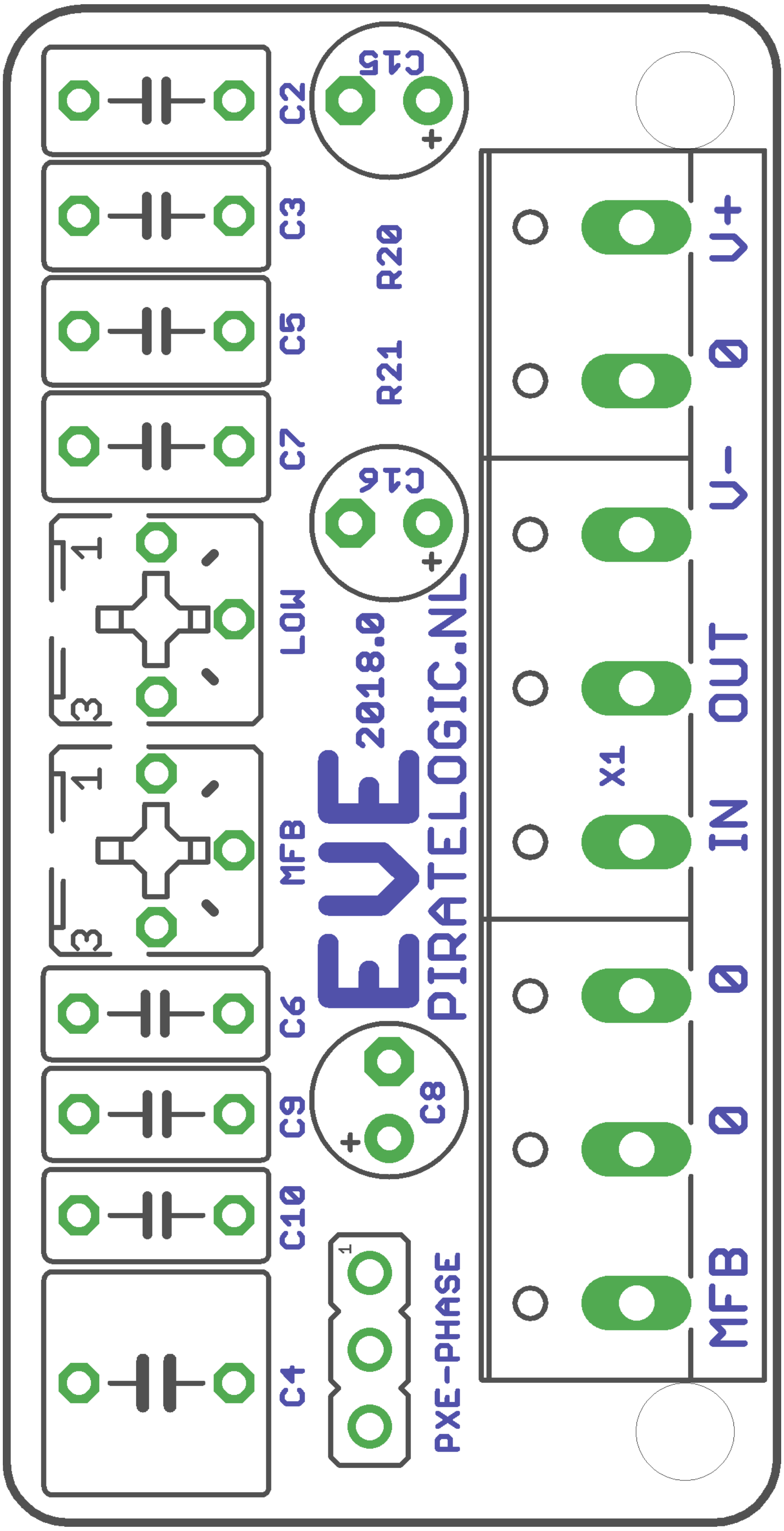




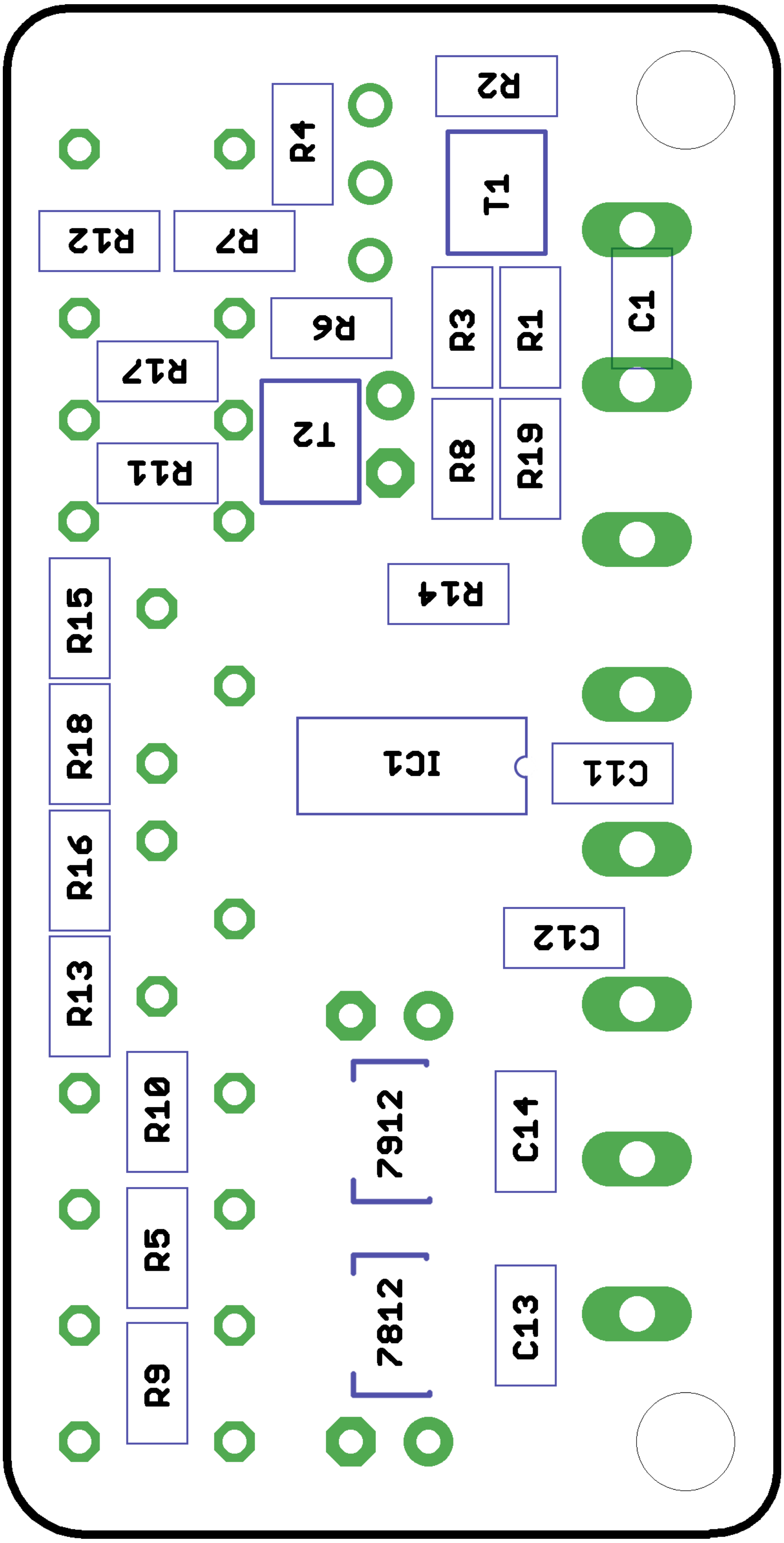
Schematic


PIRATELOGIC.NL
motionalfeedback audio
MAY THE MUSIC PASSING THROUGH THIS DEVICE
SOMEHOW HELP TO BRING JUST A LITTLE MORE
PEACE TO THIS TROUBLED WORLD.
EVE
2018.0
HIGH PASS
LOW PASS
PXE BUFFER
PXE PHASE
PXE GAIN
LOOP MIXER
IC1A TL074D
IC1B TL074D
IC1C TL074D
IC1D TL074D
7812
7912
BCV62 T1
T2 BC849
PXE-PHASE
MFB
LOW

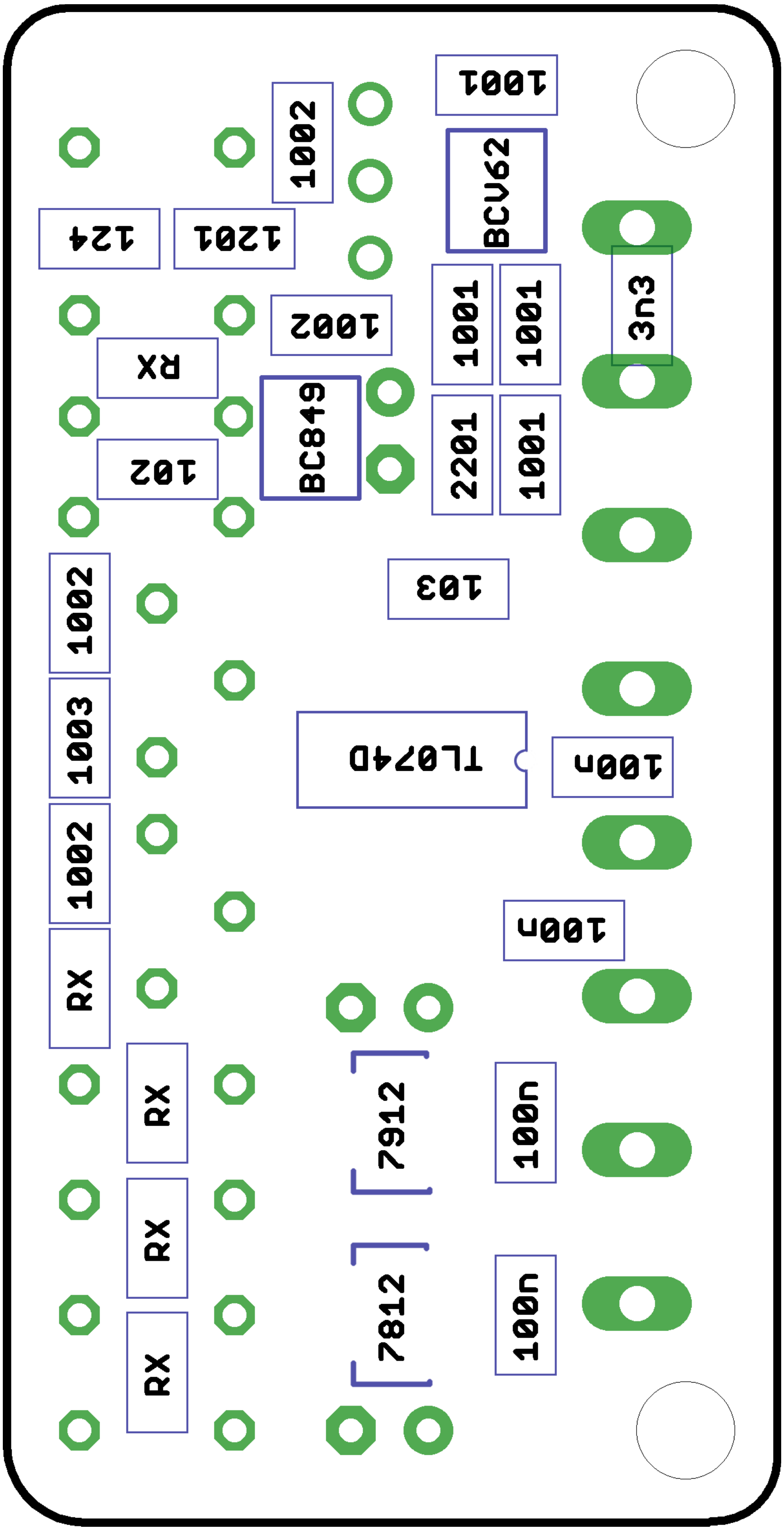
PCB Layout – top



PCB Layout – bottom names

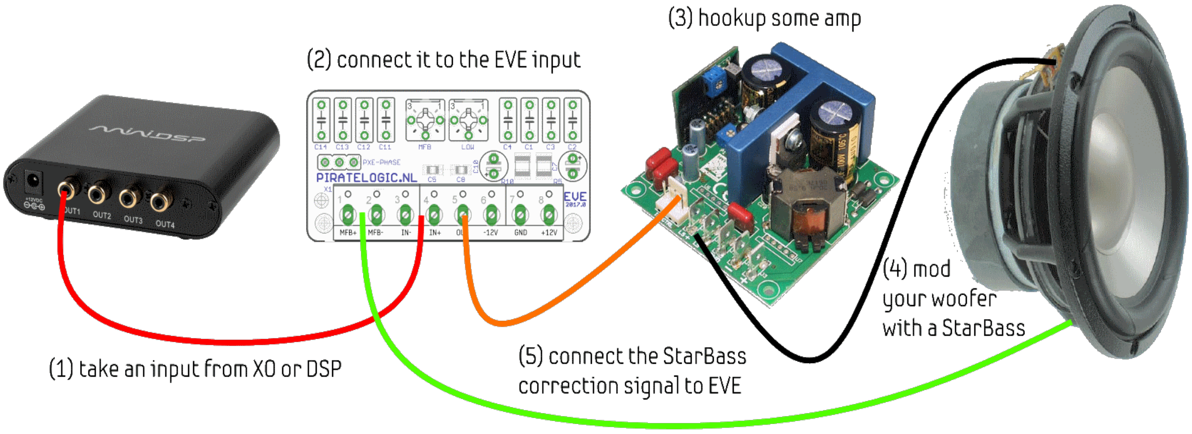


PCB Layout – bottom values



Custom versions

Eve accepts standard asymmetric line-level audio coming from either a mixer, preamp, phone or any other sound source and should be hooked up as shown below.



Acceleration Sensors

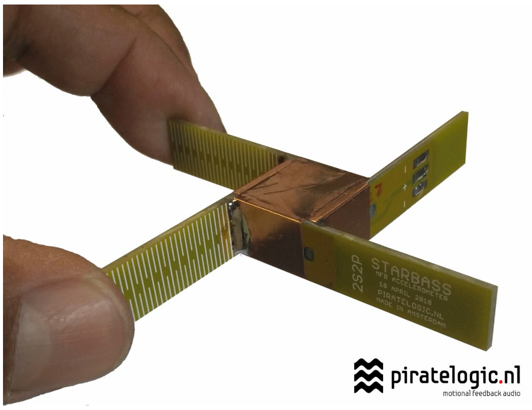
One of EVE's design criteria was to make it a Swiss Tool for building motional feedback loops and as such contains a fully configurable filter and correction section, as such EVE supports a wide variety of accelerometers ranging from vintage Philips sensors to the latest StarBass models.

Since sensor output depends on it's sensitivity, frequency response, enclosure Q factor, driver diameter etc EVE 2018.0 has been fitted with an adjustable PXE gain allowing use of a wide variety of acceleration sensors:

EVE supports the original Philips MFB sensors, both the original 532, 541,544,567 and 545 10M sensor as well as the 585, 586 and 587 33M sensors. EVE has not been tested with the ACH01 sensor but should have no problems processing it's input.

Piratelogic Little/One , StarBass and ClingOn sensors

EVE supports both Piratelogic StarBass and future ClingOn accelerometers.



Driver modification

Overall design considerations

Designing a low note system starts with choosing main design parameters like sound presure level, dispersion pattern, power bandwidth etc, for the most of it designing a MFB system follows identical rules and logic with the exception of some important design considerations unique to MFB that need highlighting:

- As the feedback loop will attempt to mimic physical cone movement to amplifier input ported designs exhibiting a helmholtz resonance will not work without extensive loop tuning.
- MFB exchanges acoustical power output for lownote extension, if it's purely SPL you are looking for MFB might not be your weapon of choice, the extra fundament comes at a price.
- Operating a driver / enclosure below it's physical resonance F3box requires extra amplifier power.
- Forcing a driver / enclosure to mimic the incoming electrical waveform requires extra amplifier power.
- The extra amplifier power has thermal consequences for the driver motor system and requires extra care not to exceed thermal power handling and safe operating areas, specially since motor cooling by natural convection

Driver selection criteria

Selecting a driver for use with motional feedback systems requires attention to the following specific design details:

Cone size / material : make sure the driver does not exhibit cone breakup in the area mfb is active in. The larger the driver the harder it will be for it to maintain pistonic operation. For high SPL designs consider that multiple smaller diameter drivers might yield better results then a single large one, small lightweight & sturdy cones are favourable over large and heavy ones.

High BL: to maximise mfb control over the driver cone movement a strong motor system is required.

High Xmax : depending on the desired power bandwidth and used cabinet Q the driver needs to linearly move as much air as possible.

Low CMS : a too high value in combination with MFB will severely affect distortion figures due to the deformation of the surround caused by the constant compression and decompression of the air behind the driver. This is especially comes into play with Qbox designs above 0.7.

Ventilated polepiece : to allow convection of heat away from the voice coil as quickly as possible. Note that since MFB required a closed cabinet the temperature inside the enclosure will be considerably higher compared to vented enclosures. Aluminium cones exhibit better heat transfer characteristics then carbon / non metalic models.

High temp voicecoil former : usage of vintage – paper – voicecoil formers severely restrict the powerhandling.

Errata

Please note the V- and V+ captions for the X1-8 and X1-6 power connection are incorrect labelled on the PCB, for the correct labelling please refer to **PCB Layout – top** on page #12 of this manual.

Document history

Prior to starting work please check if the date & time stamp at the footer of this page corresponds with the one in the online version :

https://piratelogic.nl/data/docs/products/eve/piratelogic.eve.2018.0.manual.en.pdf

10-01-19	initial version by CC.		
17-01-19	Updated schematics & pcb images.		
28-01-19	C8 / C9 typo fixed, thanks Timo Haapsaari :-)		
20-02-19	Added loopphase info, thanks jeroen@daudio.		
01-03-19	Added ERRATA on incorrect labelling of X1-8 and X1-6 power connections.		
09-03-19	Added SOT89 pin layout info & R9 fix for disabling the rumble filter.		
27-03-19	Updated schematics & bom, thanks Rob Campell.		
26-07-19	Updated images / wording.		
01-10-19	Updated BOM / Made a start with adding driver mod info.		