RAT distortion pedal

29-01-2022

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Version 1.0

I. Version history

Version	Changes
1.0	First version

II. Table of contents

1. Product description

The distortion pedal is a guitar effect used to create a distortion effect. It is based on the ProCo Rat distortion pedal from the late 1970s. A pedal analysis reference [1] by Electrosmash is used as a design guideline. A general brief explanation on clipping diodes by Guitarpedalx.com [2] is also used as an information reference.

A custom PCB is designed for the effect. The design consists of 4 stages.

The power stage accepts the standard 9 volts for guitar pedals. It is fused via a PTC 100mA fuse and protected against reverse polarity via a diode. The power stage contains a low pass filter to filter out noise. A voltage divider is used to create 4.5 volts used as a virtual ground for the opamp in the distortion stage.

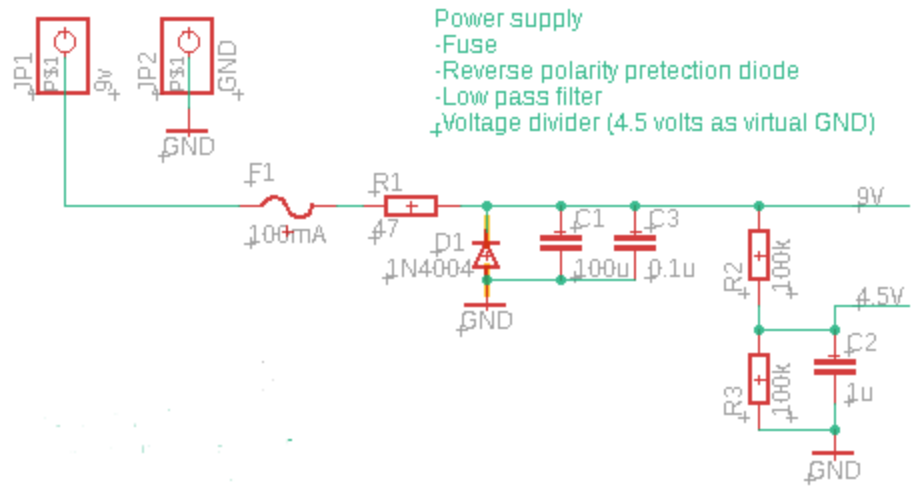
The distortion stage uses a LM308 or OP07D opamp. Clipping diodes are used to create the distorted sounds. A potentiometer can be used to adjust the amount of distortion

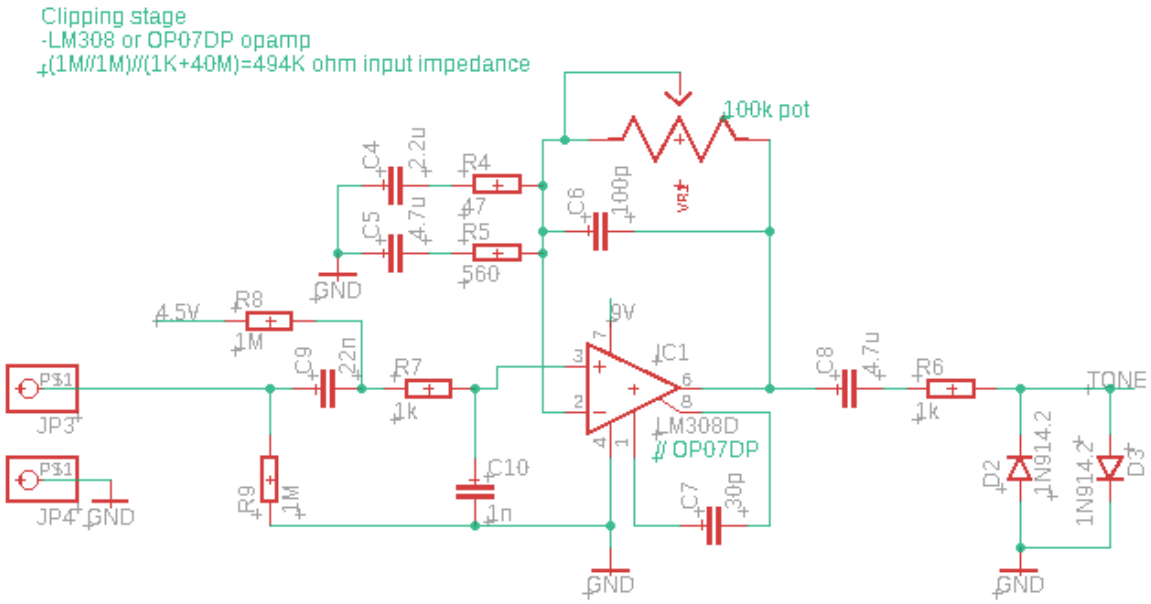
A filter stage consists of a simple low pass filter controlled by the second potentiometer. This potentiometer adjusts the R component in the filter to set the cut off point between about 32KHz and 475Hz. Higher harmonics are filtered out by this stage to differ the tone.

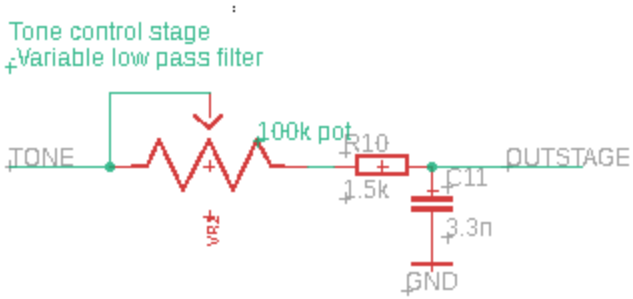
An output power stage is used to create a low output impedance and a volume control that is not affected by the distortion and tone controls. The volume can be adjusted by the third potentiometer.

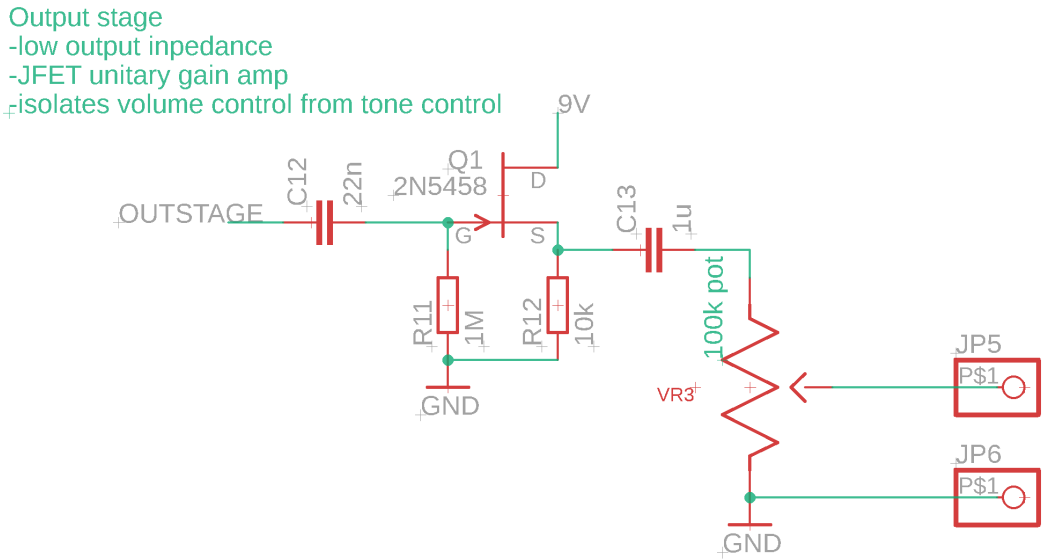
The effect is housed in an aluminum pedal housing. Power can be supplied via a DC 9v barrel jack (center negative). For the audio in- and output 6.35mm mono audio jacks are used. A stomp switch is used to create a true bypass. This is wired according to the schematic “True bypass with LED” by Stinkfoot.se [3].

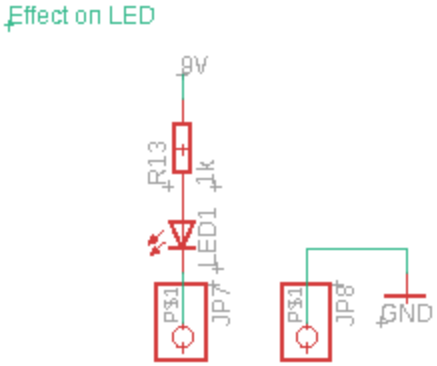
2. Schematics

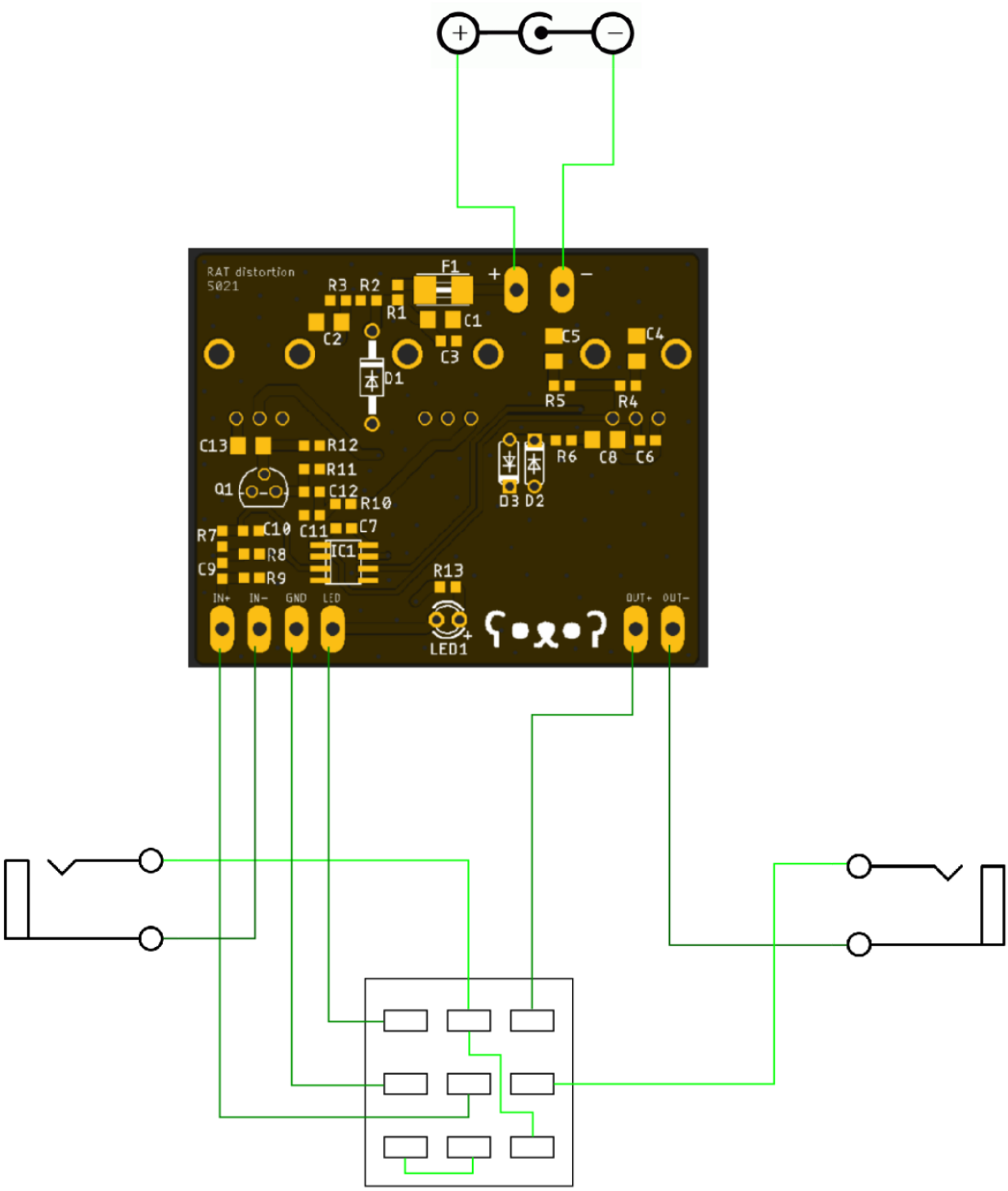





Tone control stage
Variable low pass filter
TONE
100k pot
VR2
R10
1.5k
C11
3.3n
GND
OUTSTAGE

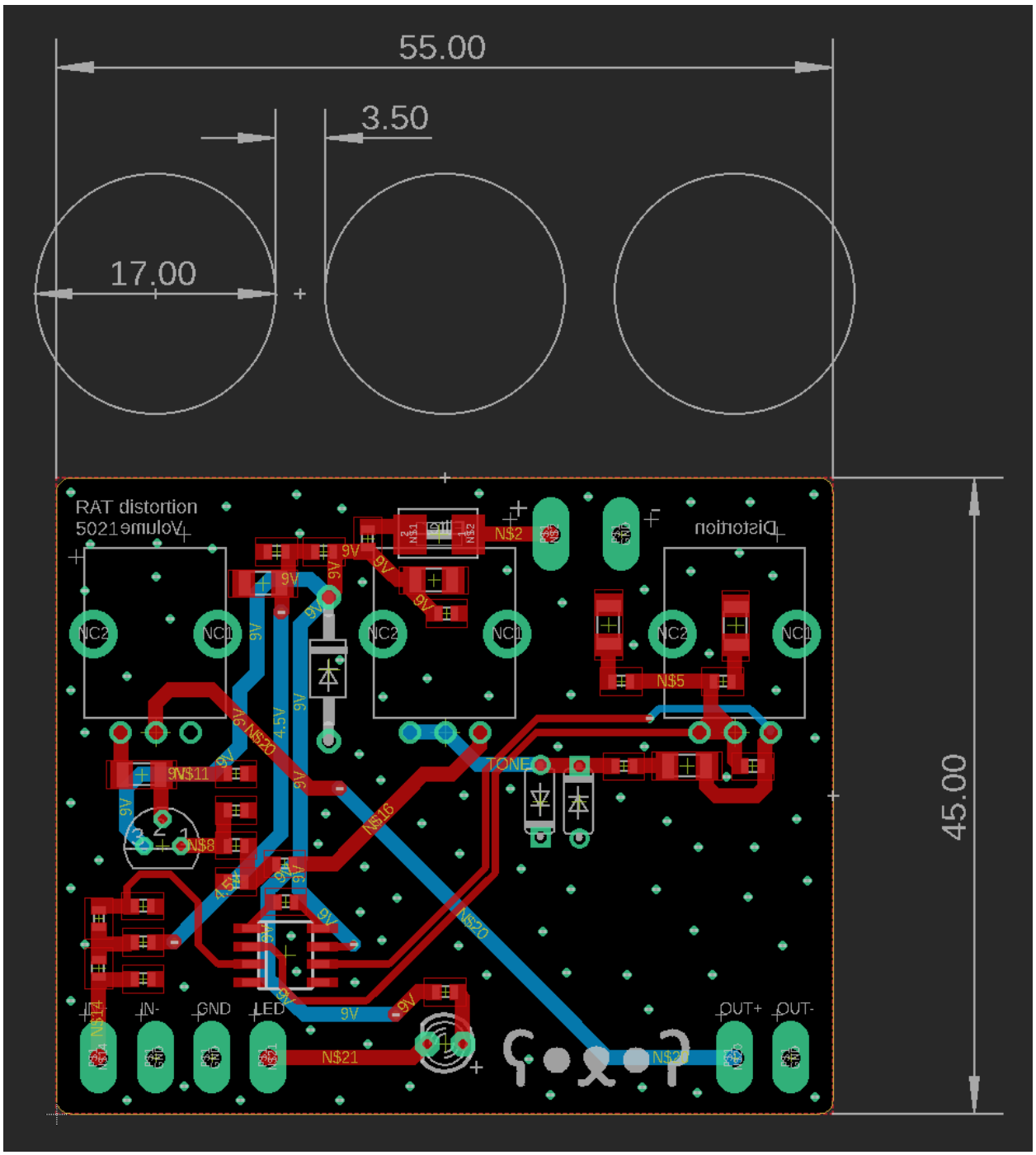

Output stage
-low output inpedance
-JFET unitary gain amp
-isolates volume control from tone control
9V
OUTSTAGE
C12
22n
Q1
2N5458
D
G
S
C13
1u
R11
1M
R12
10k
GND
100k pot
VR3
JP5
P$1
JP6
P$1
GND


Effect on LED
9V
R13
1k
LED1
P$1
JP7
P$1
JP8
GND

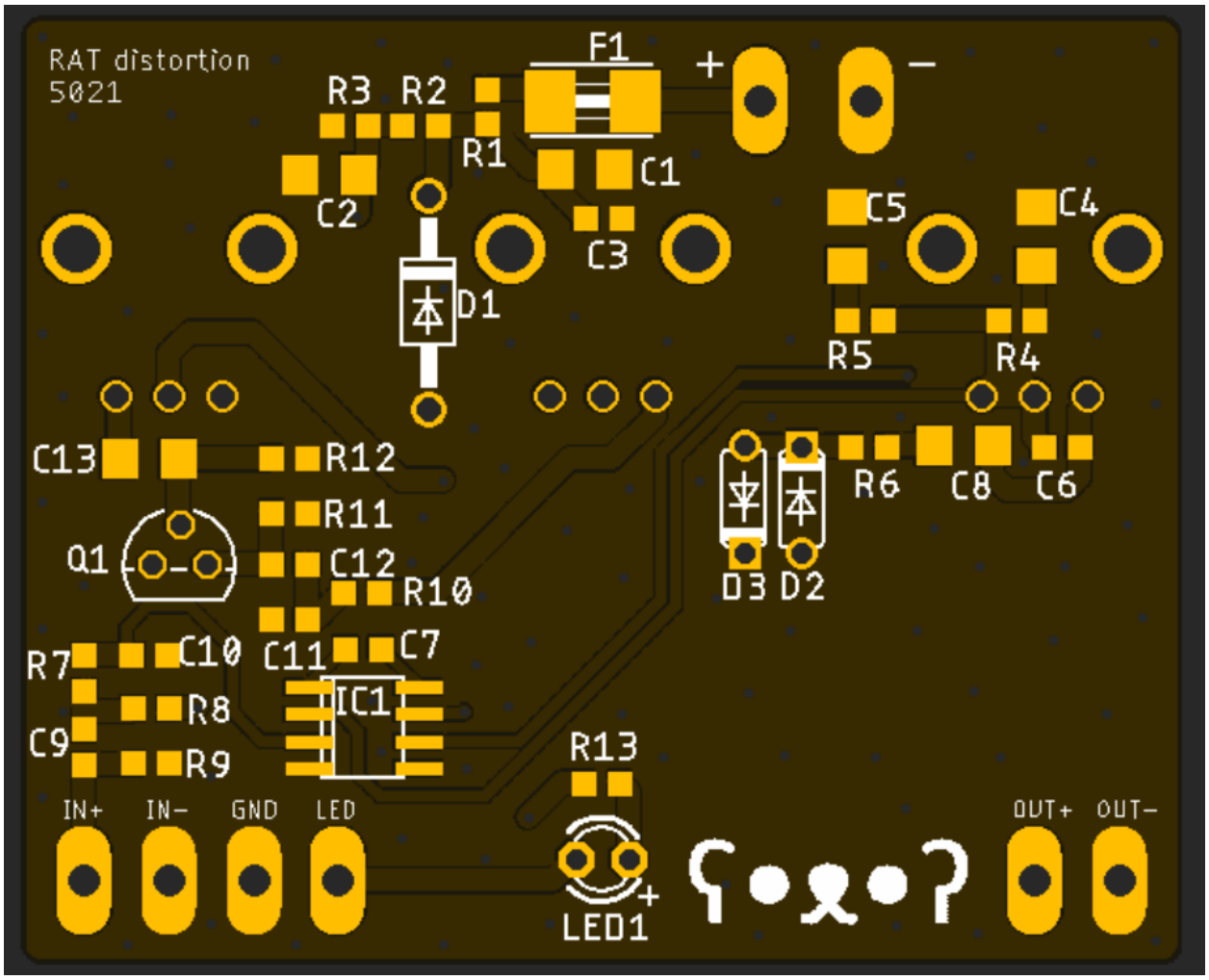

RAT distortion
5021
F1
+
−
R3
R2
R1
C1
C2
C3
D1
C5
C4
R5
R4
C13
R12
R11
Q1
C12
R10
C10
C11
C7
R7
R8
C9
R9
IC1
R13
D3
D2
R6
C8
C6
IN+
IN−
GND
LED
LED1
OUT+
OUT−

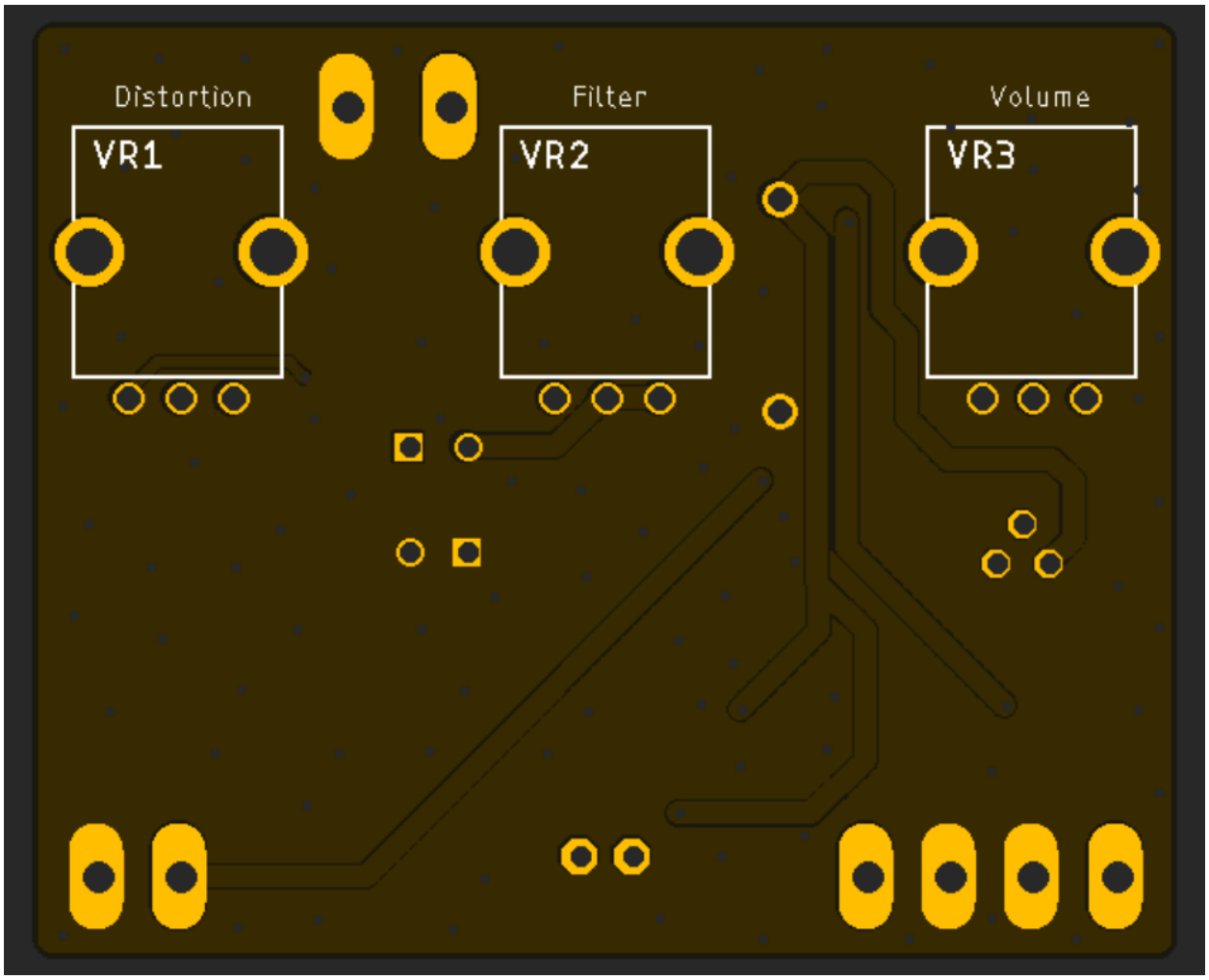
3. PCB layout

The PCB design is as shown in the picture below. The dimensions of the PCB are also shown in the drawing. The circles shown in the dimensions are there to show the space between the potentiometer knobs.



Note: Component number not visible on real PCB


RAT distortion
5021
F1
+
−
R3
R2
R1
C1
C2
C3
D1
C5
C4
R5
R4
C13
R12
R11
C12
R10
Q1
C10
C11
C7
R7
R8
C9
R9
IC1
D3
D2
R6
C8
C6
R13
IN+
IN−
GND
LED
OUT+
OUT−
LED1

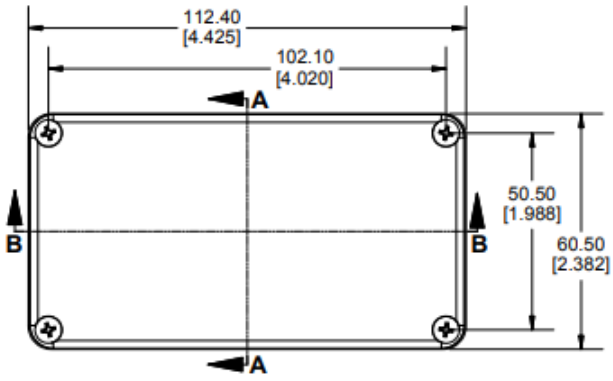

Distortion
VR1
Filter
VR2
Volume
VR3

4. Bill of materials

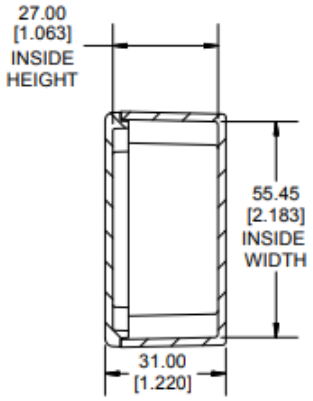
Part number	Device	Footprint	Type / value	Total parts
C1	Capacitor	1206	100uF	1
C2, C13	Capacitor	1206	1uF	2
C3	Capacitor	0603	0.1uF	1
C4	Capacitor	1206	2.2uF	1
C5, C8	Capacitor	1206	4.7uF	2
C6	Capacitor	0603	100pF	1
C7	Capacitor	0603	30pF	1
C9, C12	Capacitor	0603	22nF	2
C10	Capacitor	0603	1nF	1
C11	Capacitor	0603	3.3nF	1
D1	Diode	DO41	1N4004	1
D2, D3	Diode	DO35	1N914	2
F1	PTC fuse	1812	100mA	1
IC1	Opamp	SOP8	LM308d OP07CDR (alternative)	1
Q1	JFET	TO92	2N5458	1
LED1	LED	3mm trough hole	3mm LED	1
R1, R4	Resistor	0603	47 ohm	2
R2, R3	Resistor	0603	100k ohm	2
R5	Resistor	0603	560 ohm	1
R6, R7, R13	Resistor	0603	1k ohm	3
R8, R9, R11	Resistor	0603	1M ohm	3

R10	Resistor	0603	1.5k ohm	1
R12	Resistor	0603	10k ohm	1
VR1, VR2, VR3	Potentiometer	PTV09 RK09N (alternative)	100k ohm A (log)	3
Foot switch	Stomp switch	3PDT	3PDT	1
DC in	DC power jack	DC-022	DC-022	1
Audio in, Audio out	Audio jack	6.35mm	6.35mm	2
Housing	Housing	1590B	1590B	1
Pot knobs	Knobs	6mm pot knob	17X13 for 6mm shaft with teeth	3
Wiring	Wire	0.2 mm^2	0.2 mm^2	-
PCB	PCB	45mmx55mm	-	1
Solder paste	Solder	Bi57Sn42Ag1	Bi57Sn42Ag1	-
Solder wire	Solder	Sn60Pb39Cu1	Sn60Pb39Cu1	-
Heatshrink	Heatshrink	-	-	-

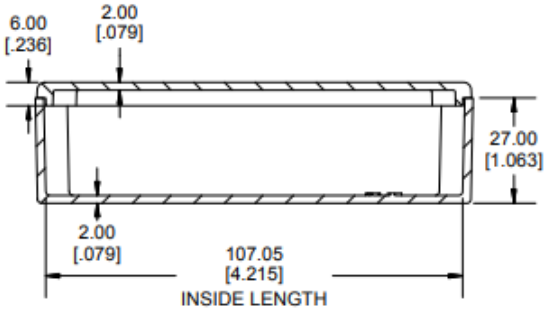
5. Housing dimensions



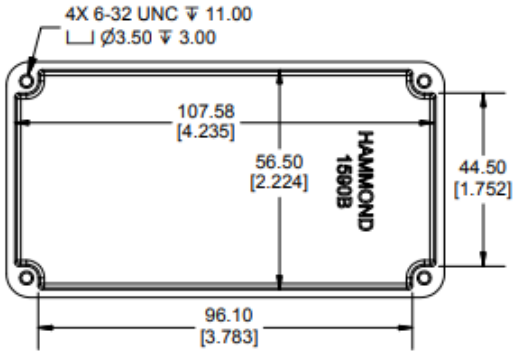
TOP VIEW



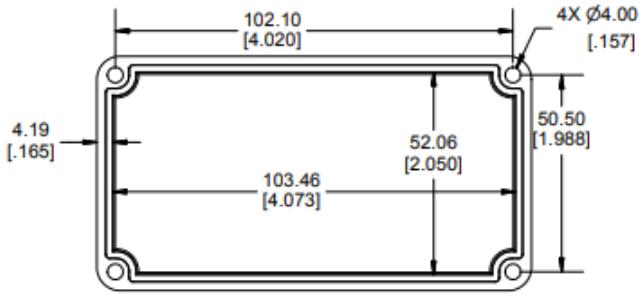
SECTION A-A
END VIEW



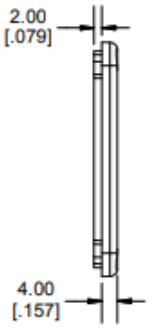
SECTION B-B
SIDE VIEW



INSIDE BOX

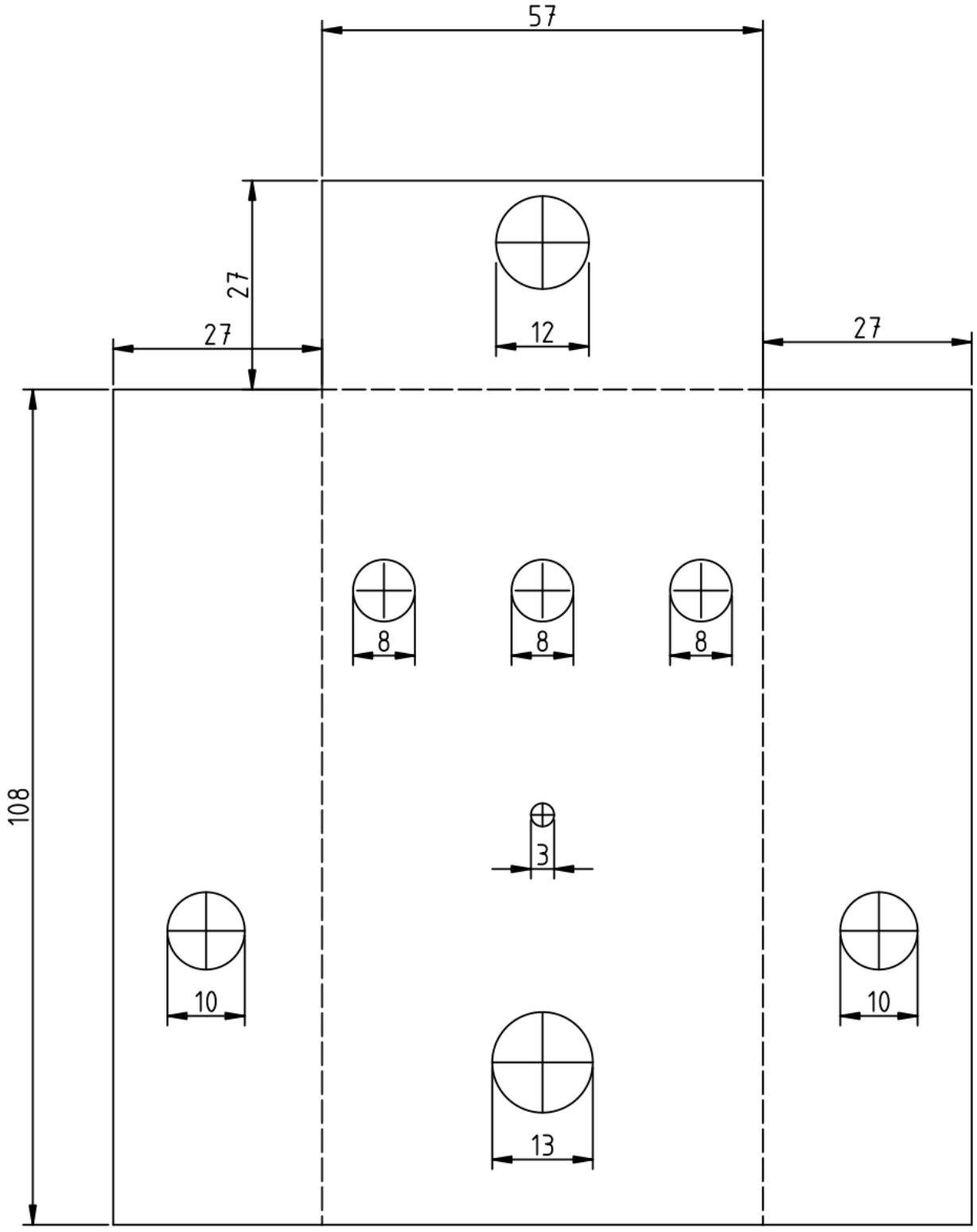


INSIDE LID



Dimensions:
mm
[inches]

6. Drill template



See “RAT distortion drill template.pdf” and “RAT distortion drill template.dxf”. Make sure to print the template on 100% scaling.

7. Development costs

Only the material costs are included in the development costs.

Part number	Device	Type / value	Total parts ordered	Total parts price (€)	Shipping price (€)	Total price incl shipping (€)	Total price per piece (€)	Link (at time of order)	Remark
C1	Capacitor	100uF	-	-	-	-	-	Digikey	From stock
C2, C13	Capacitor	1uF	100	1,03	0,53	1,56	0,02	Aliexpress	
C3	Capacitor	0.1uF	-	-	-	-	-	Digikey	From stock
C4	Capacitor	2.2uF	100	1,19	0,53	1,72	0,02	Aliexpress	
C5, C8	Capacitor	4.7uF	100	1,19	0,53	1,72	0,02	Aliexpress	
C6	Capacitor	100pF	100	0,83	0,53	1,36	0,01	Aliexpress	
C7	Capacitor	30pF	100	0,83	0,53	1,36	0,01	Aliexpress	
C9, C12	Capacitor	22nF	100	0,83	0,53	1,36	0,01	Aliexpress	
C10	Capacitor	1nF	100	0,83	0,53	1,36	0,01	Aliexpress	
C11	Capacitor	3.3nF	100	0,83	0,53	1,36	0,01	Aliexpress	
D1	Diode	1N4004	100	1,17	0,53	1,70	0,02	Aliexpress	
D2, D3	Diode	1N914	50	0,44	2,05	2,49	0,05	Aliexpress	
F1	PTC fuse	100mA	20	0,67	2,11	2,78	0,14	Aliexpress	
IC1	Opamp	OP07CDR	10	1,10	2,31	3,41	0,34	Aliexpress	
Q1	JFET	2N5458	10	2,38	1,93	4,31	0,43	Aliexpress	Seems to be fake, measures as a NPN transistor
Q1	JFET	2N5458	5	5,45	0,00	5,45	1,09	Mouser	
Q1	JFET	J111	10	3,12	0,00	3,12	0,31	Mouser	Orderd to try, not used

LED1	LED	3mm LED	-	-	-	-	-	NA	From stock
R1, R4	Resistor	47 ohm	-	-	-	-	-	Aliexpress	From stock
R2, R3	Resistor	100k ohm	-	-	-	-	-	Aliexpress	From stock
R5	Resistor	560 ohm	-	-	-	-	-	Aliexpress	From stock
R6, R7, R13	Resistor	1k ohm	-	-	-	-	-	Aliexpress	From stock
R8, R9, R11	Resistor	1M ohm	-	-	-	-	-	Aliexpress	From stock
R10	Resistor	1.5k ohm	-	-	-	-	-	Aliexpress	From stock
R12	Resistor	10k ohm	-	-	-	-	-	Aliexpress	From stock
VR1, VR2, VR3	Potentio-meter	100k ohm A (log) RK097N	10	7,65	0,00	7,65	0,77	Aliexpress	RK097N with 6mm shaft with teeth, other types may fit
Foot switch	Stomp switch	3PDT	3	2,88	3,13	6,01	2,00	Aliexpress	
DC in	DC power jack	DC-022	10	2,09	1,44	3,53	0,35	Aliexpress	
Audio in, Audio out	Audio jack	6,35mm	10	4,89	0,00	4,89	0,49	Aliexpress	
Housing	Housing	1590B	2	14,36	1,71	16,07	8,04	Aliexpress	
Pot knobs	Knobs	17x13mm for 6mm shaft with teeth	6	3,81	3,86	7,67	1,28	Aliexpress	
Wiring	Wire	0.2 mm^2	-	-	-	-	-	Conrad	From stock
PCB	PCB	2 layer	5	11,75	14,27	26,02	5,20	JLCPCB	Custom ordered
SMD Stencil	SMD Stencil	-	1	-	-	-	-	JLCPCB	Custom ordered,

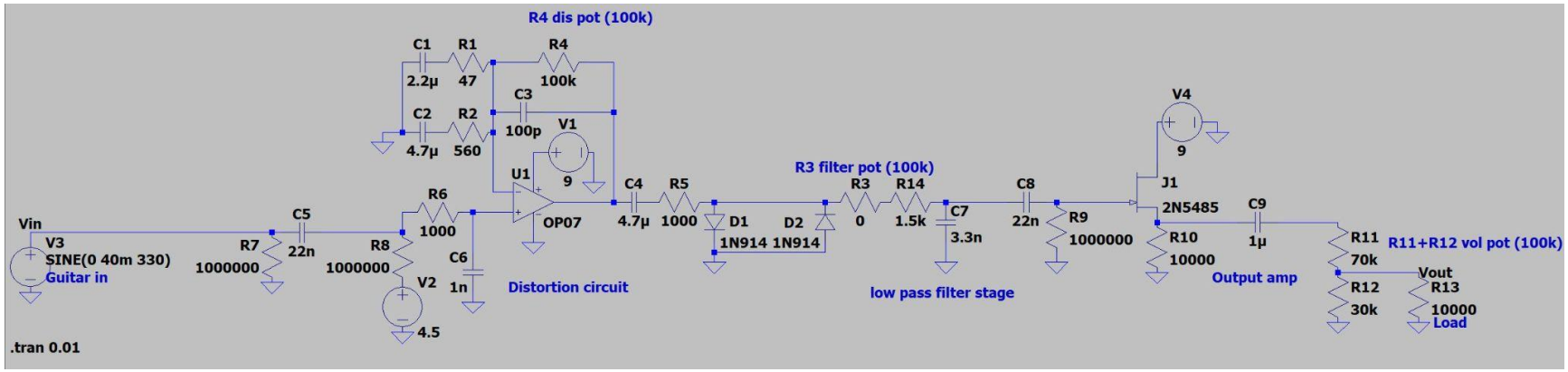
									included in PCB costs
Solder paste	Solder	Bi57Sn42-Ag1	-	-	-	-	-	Digikey	From stock
Solder wire	Solder	Sn60Pb39-Cu1	-	-	-	-	-	NA	From stock
Heat-shrink	Heat-shrink	-	-	-	-	-	-	Aliexpress	From stock

Total development costs including shipping is €106,90. Time and parts already in house are not included in this calculation.

8. Tests

The effect is simulated in LTspice XVII (see drawing on next page) to confirm the correct behavior of the effect. The opamp used in the simulation is the OP07. The output JFET is replaced with a 2N5485. This should not impact the results.

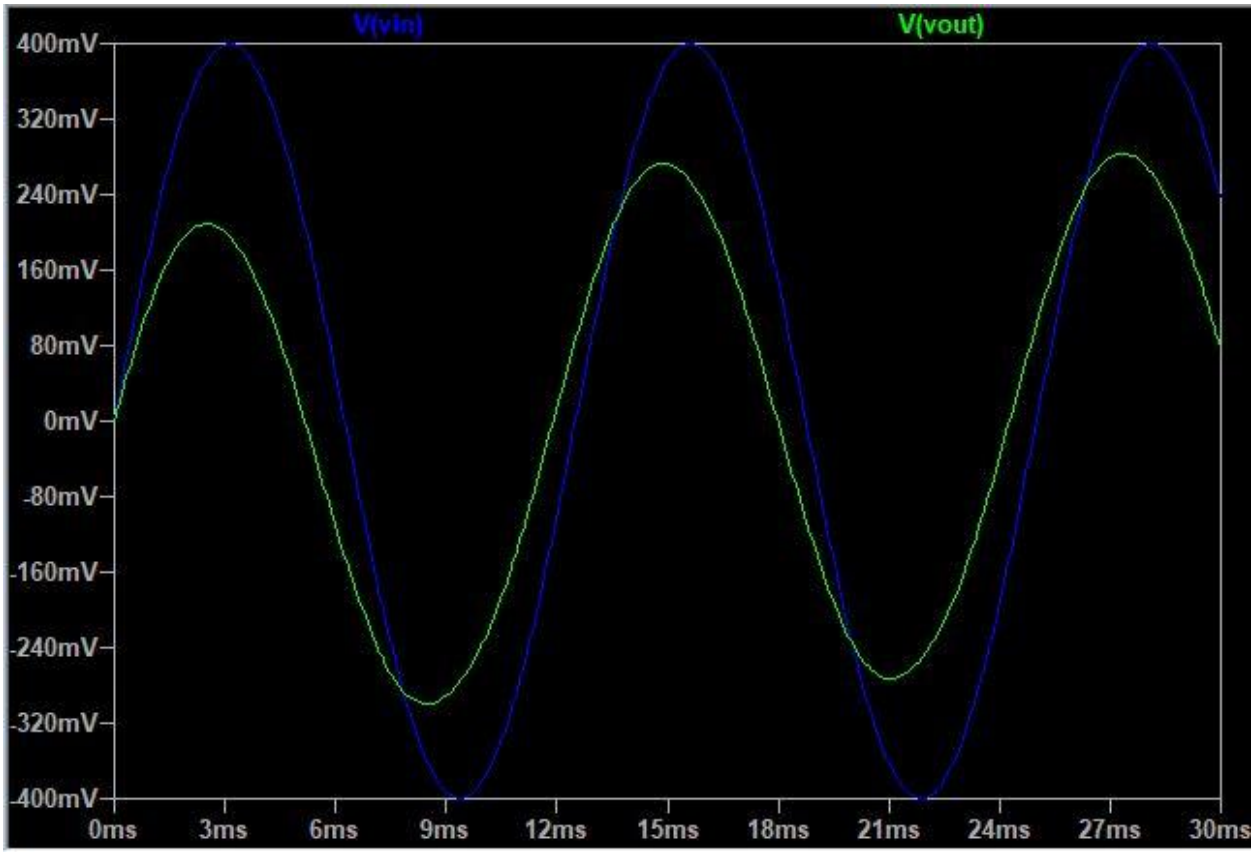
The tests are done with a 800mVpp sine wave at 80Hz and 330Hz frequencies. A 10k ohm resistor is used as a load in both the simulation and real tests.

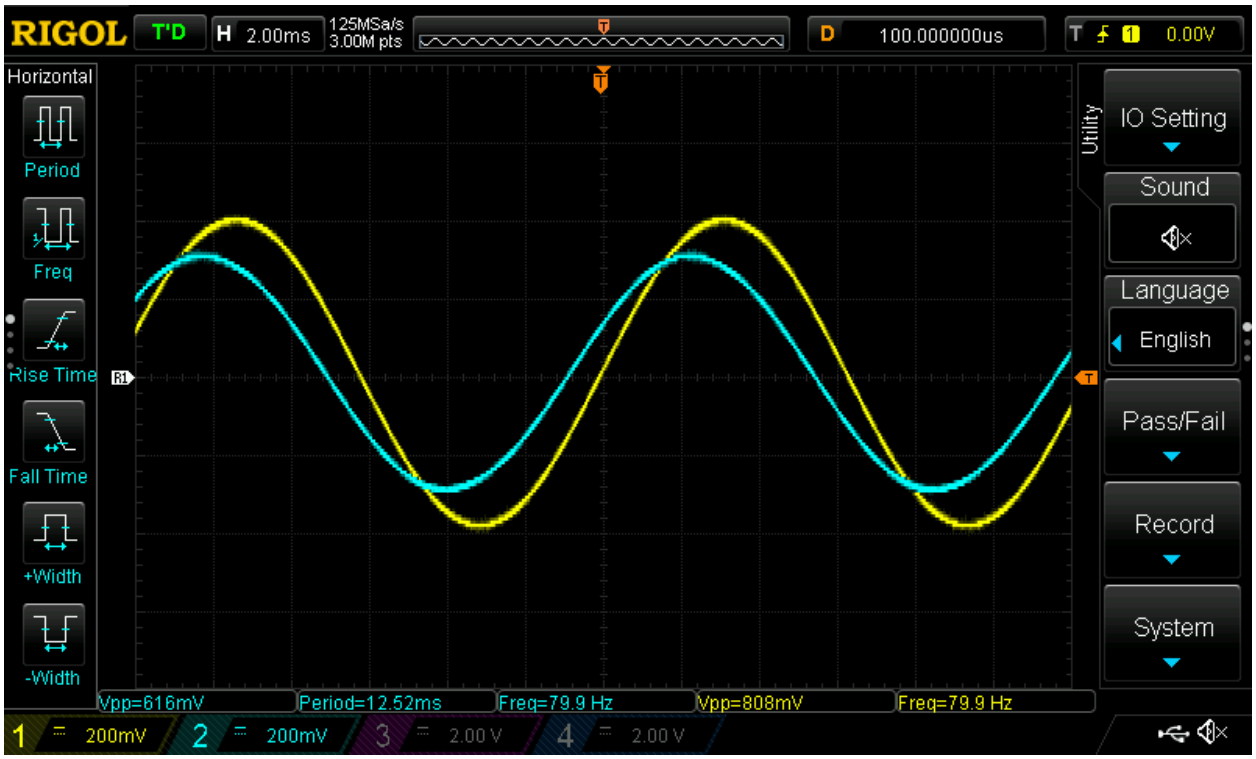

R4 dis pot (100k)
C1
R1
R4
2.2µ
47
100k
C3
C2
R2
100p
V1
4.7µ
560
9
U1
R6
C4
R5
R3 filter pot (100k)
R3
R14
C8
V4
9
J1
2N5485
C9
Vin
V3
SINE(0 40m 330)
Guitar in
R7
1000000
C5
22n
R8
1000000
1000
OP07
4.7µ
1000
D1
1N914
D2
1N914
0
1.5k
C7
3.3n
22n
R9
1000000
R10
10000
1µ
R11
70k
R11+R12 vol pot (100k)
C6
1n
V2
4.5
Distortion circuit
low pass filter stage
Output amp
R12
30k
Vout
R13
10000
Load
.tran 0.01

8.1. Low distortion 80Hz

Settings:

- Distortion 0%
- Filter 0%
- Volume 100%
- 80Hz input sine wave

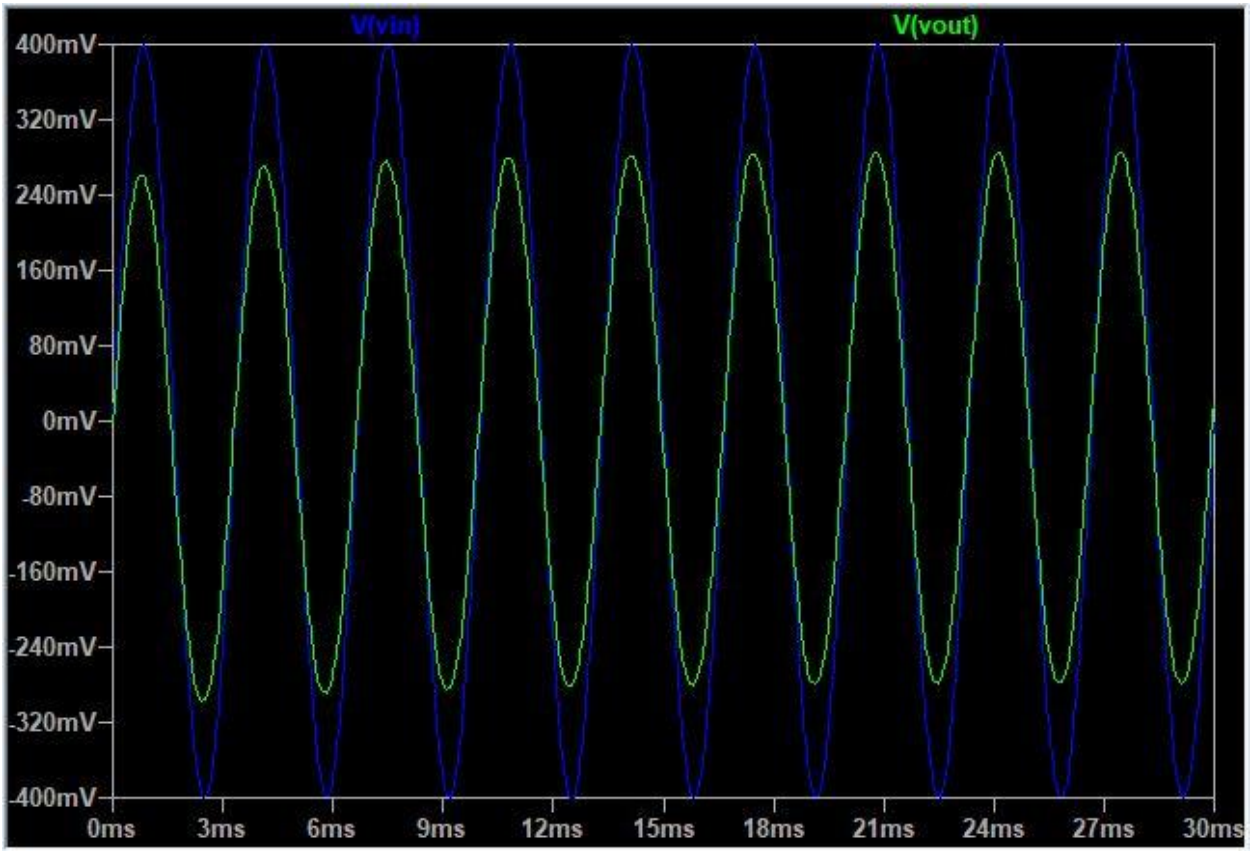




8.3. Low distortion 300Hz

Settings:

- Distortion 0%
- Filter 0%
- Volume 100%
- 300Hz input sine wave

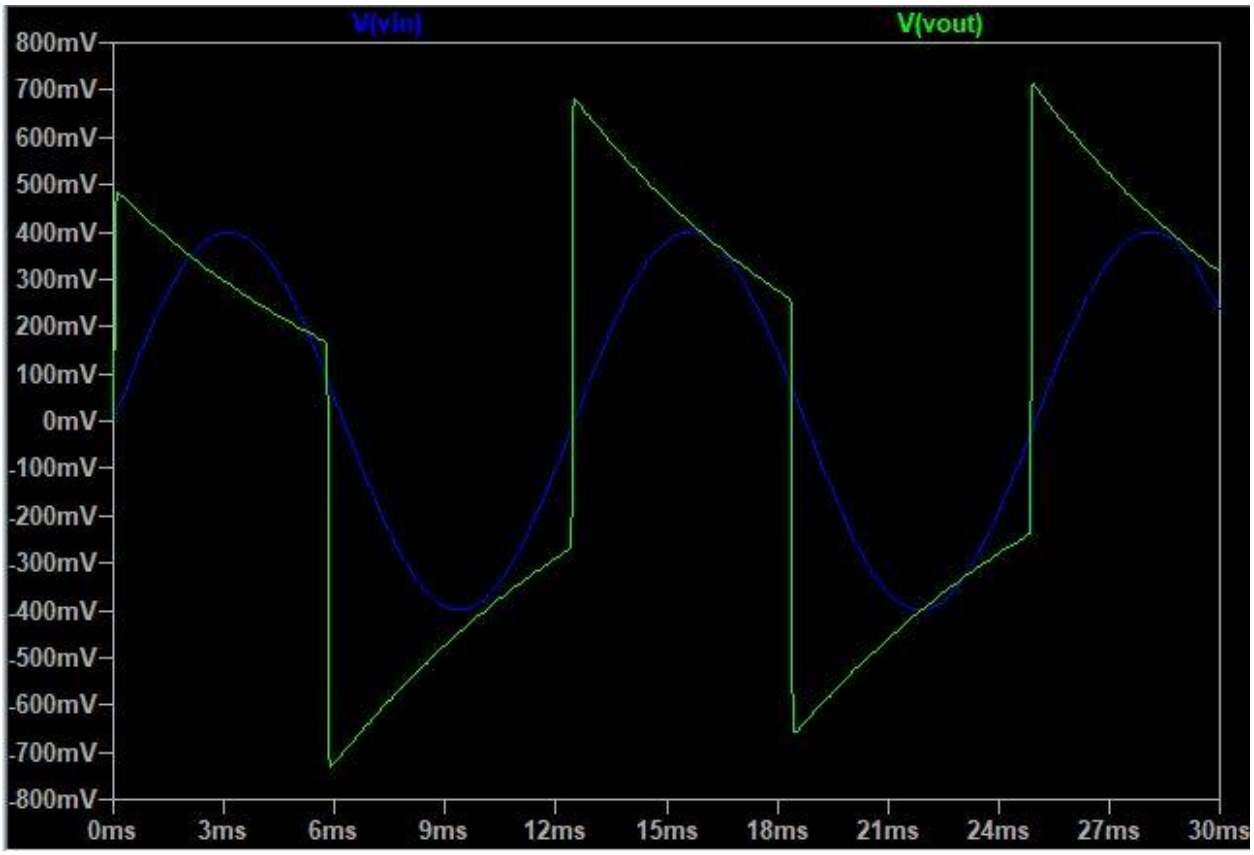

V(vin)
V(vout)
400mV
320mV
240mV
160mV
80mV
0mV
-80mV
-160mV
-240mV
-320mV
-400mV
0ms
3ms
6ms
9ms
12ms
15ms
18ms
21ms
24ms
27ms
30ms

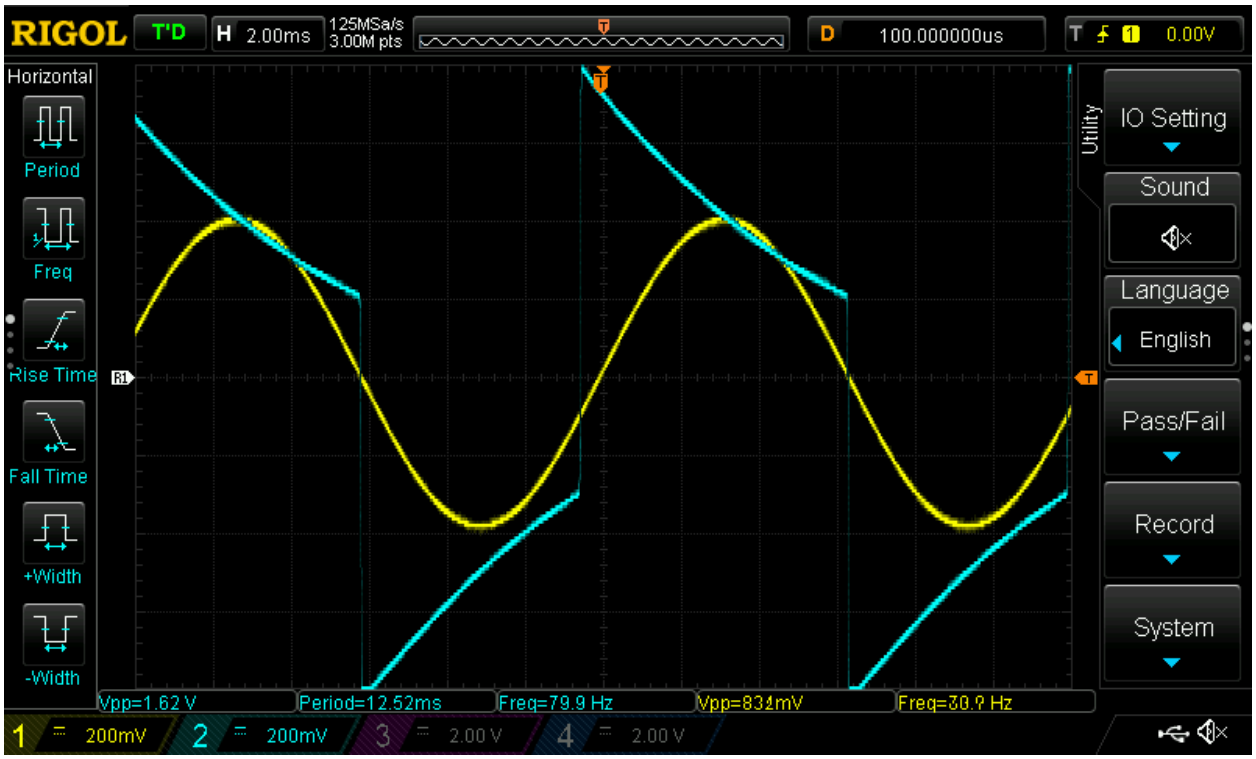

RIGOL
T'D
H 2.00ms
125MSa/s
3.00M pts
D 100.000000us
T 1 0.00V
Horizontal
Period
Freq
Rise Time
Fall Time
+Width
-Width
Utility
IO Setting
Sound
Language
English
Pass/Fail
Record
System
Vpp=640mV
Period=3.320ms
Freq=301 Hz
Vpp=808mV
Freq=301 Hz
1 200mV
2 200mV
3 2.00 V
4 2.00 V

8.2. High distortion 80Hz

Settings:

- Distortion 100%
- Filter 0%
- Volume 100%
- 80Hz input sine wave

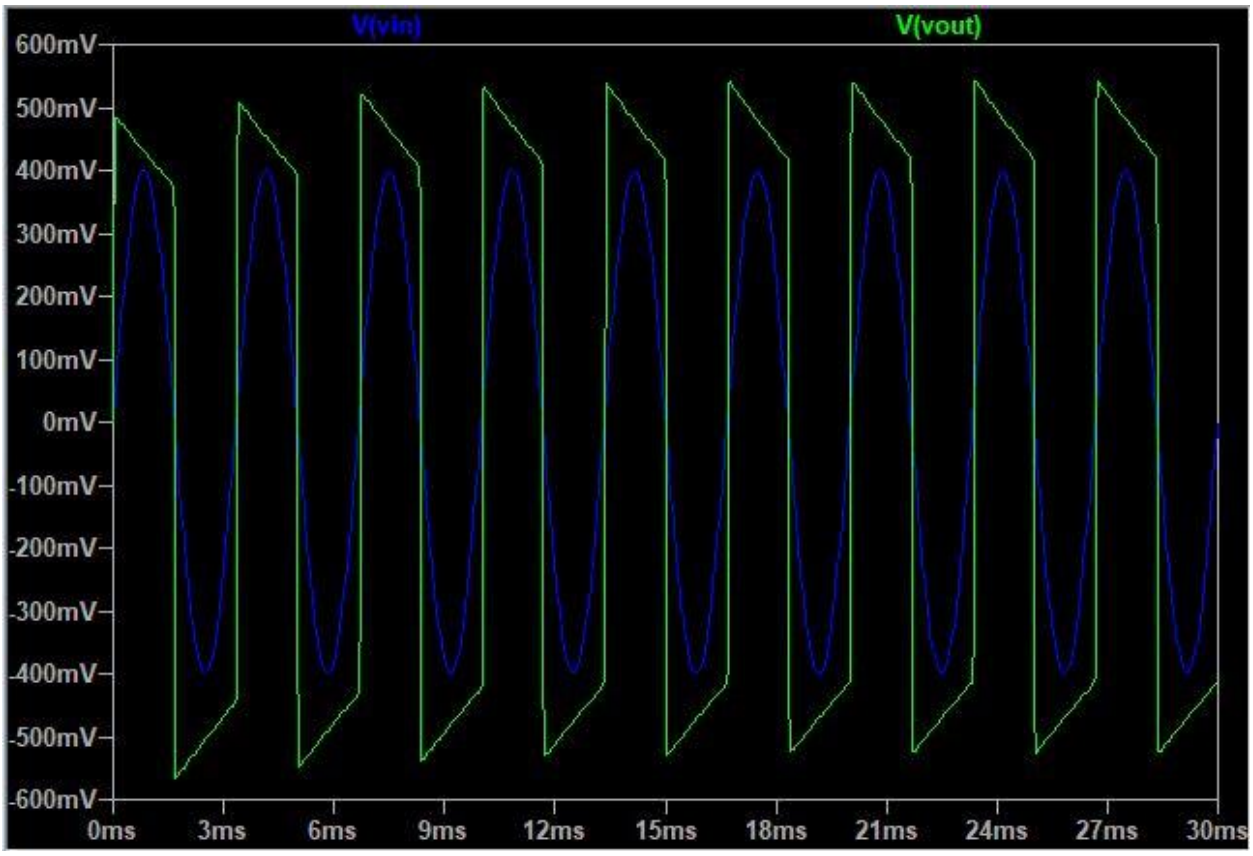


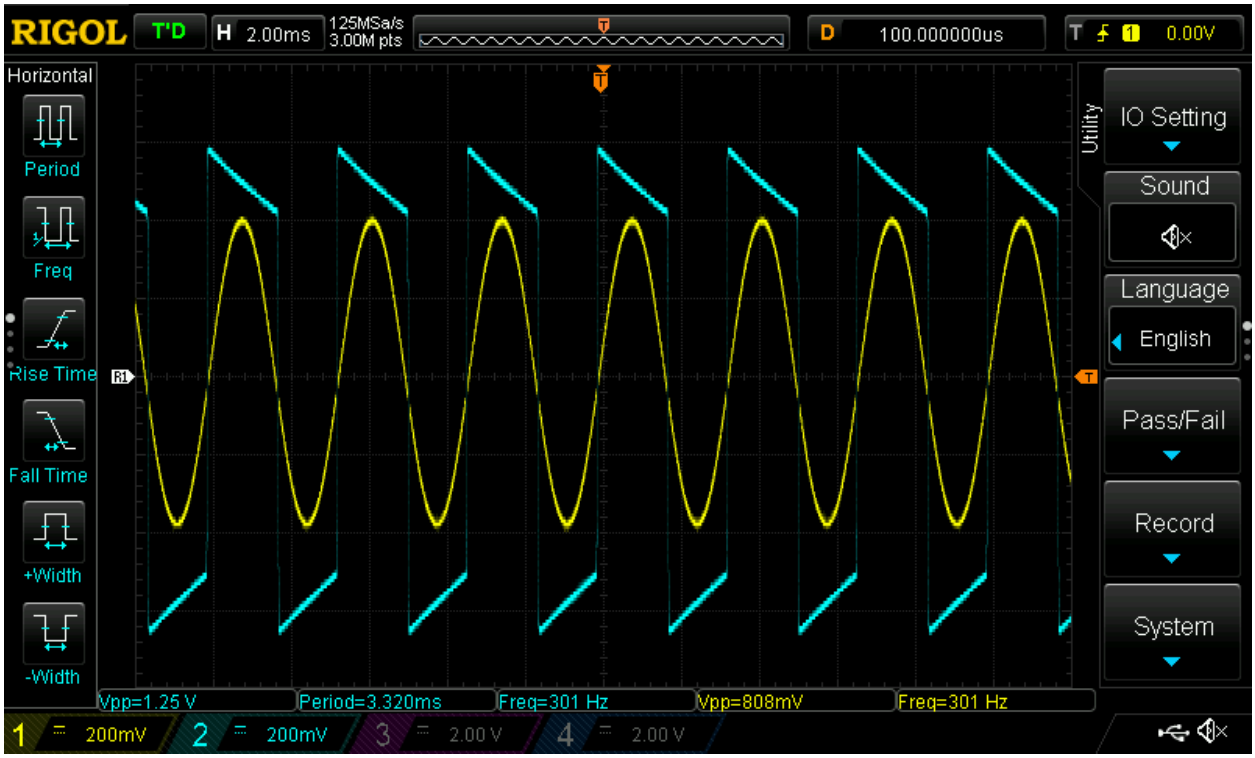


8.4. High distortion 300Hz

Settings:

- Distortion 100%
- Filter 0%
- Volume 100%
- 300Hz input sine wave

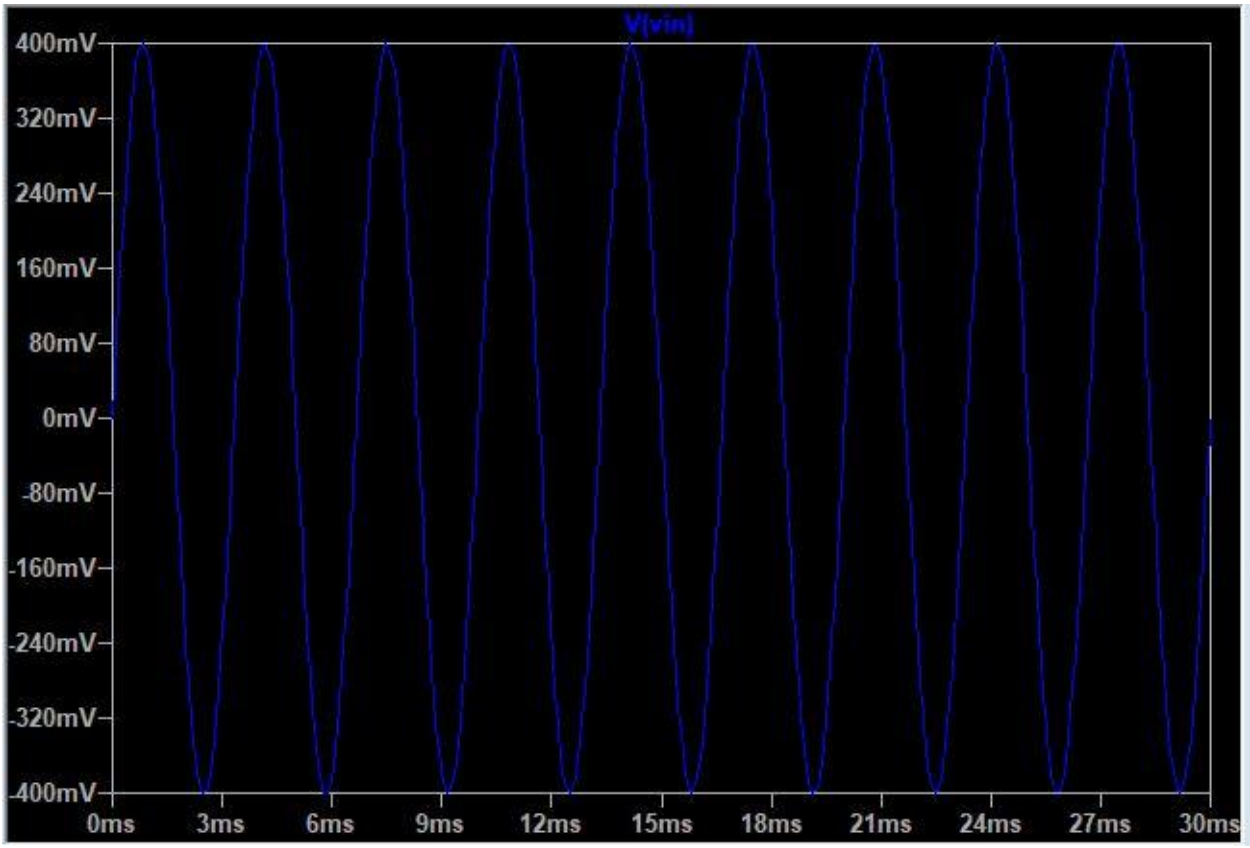

V(vin)
V(vout)
600mV
500mV
400mV
300mV
200mV
100mV
0mV
-100mV
-200mV
-300mV
-400mV
-500mV
-600mV
0ms
3ms
6ms
9ms
12ms
15ms
18ms
21ms
24ms
27ms
30ms

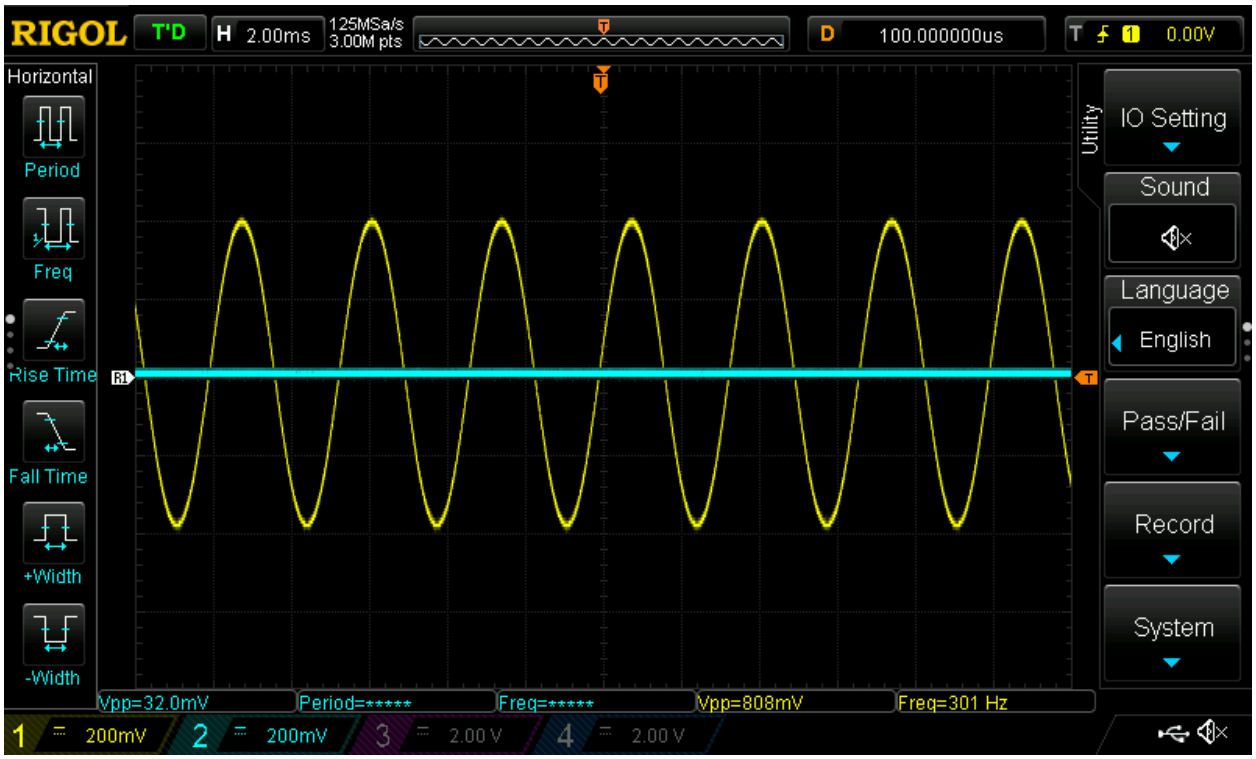

RIGOL
T'D
H 2.00ms
125MSa/s
3.00M pts
D 100.000000us
T 0.00V
Horizontal
Period
Freq
Rise Time
Fall Time
+Width
-Width
Utility
IO Setting
Sound
Language
English
Pass/Fail
Record
System
Vpp=1.25 V
Period=3.320ms
Freq=301 Hz
Vpp=808mV
Freq=301 Hz
1 200mV
2 200mV
3 2.00 V
4 2.00 V

8.5. Volume 0%

Settings:

- Distortion 100%
- Filter 0%
- Volume 0%
- 300Hz input sine wave

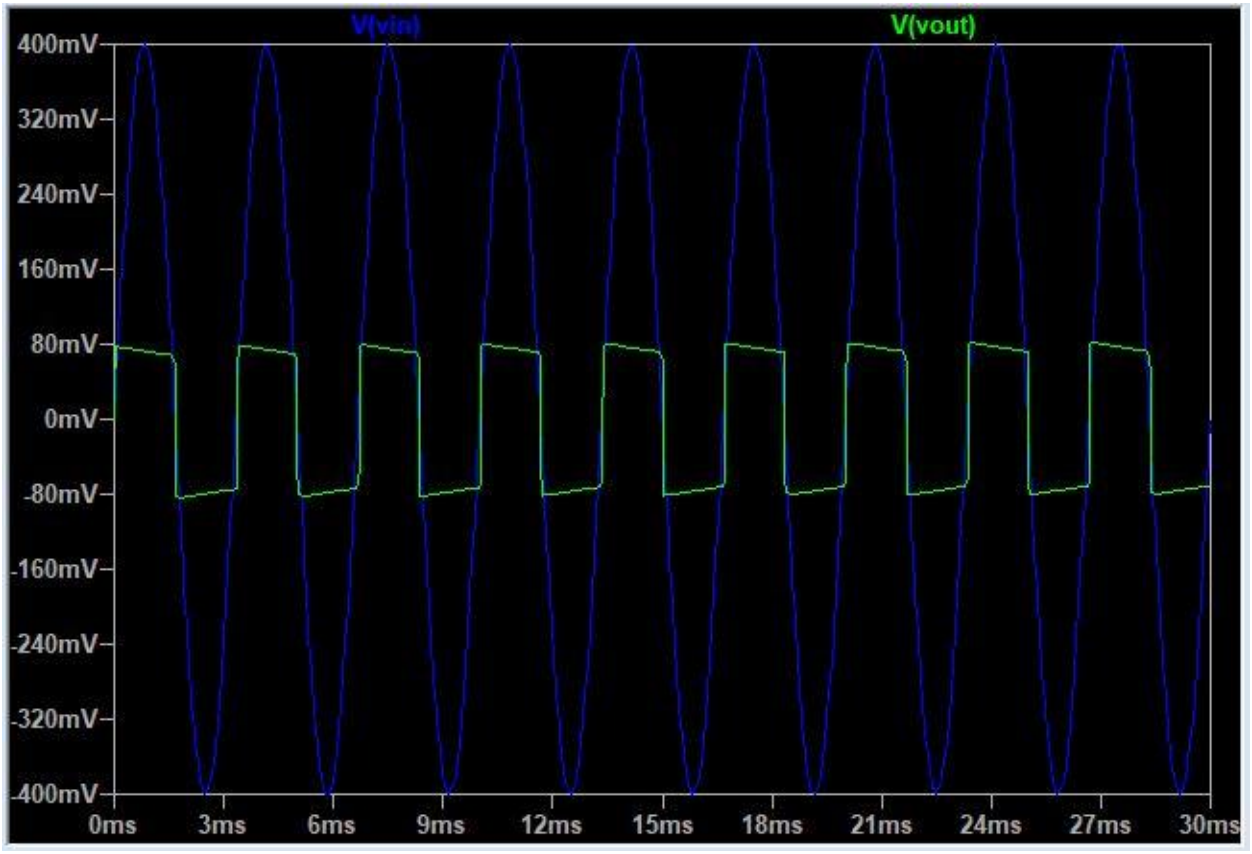


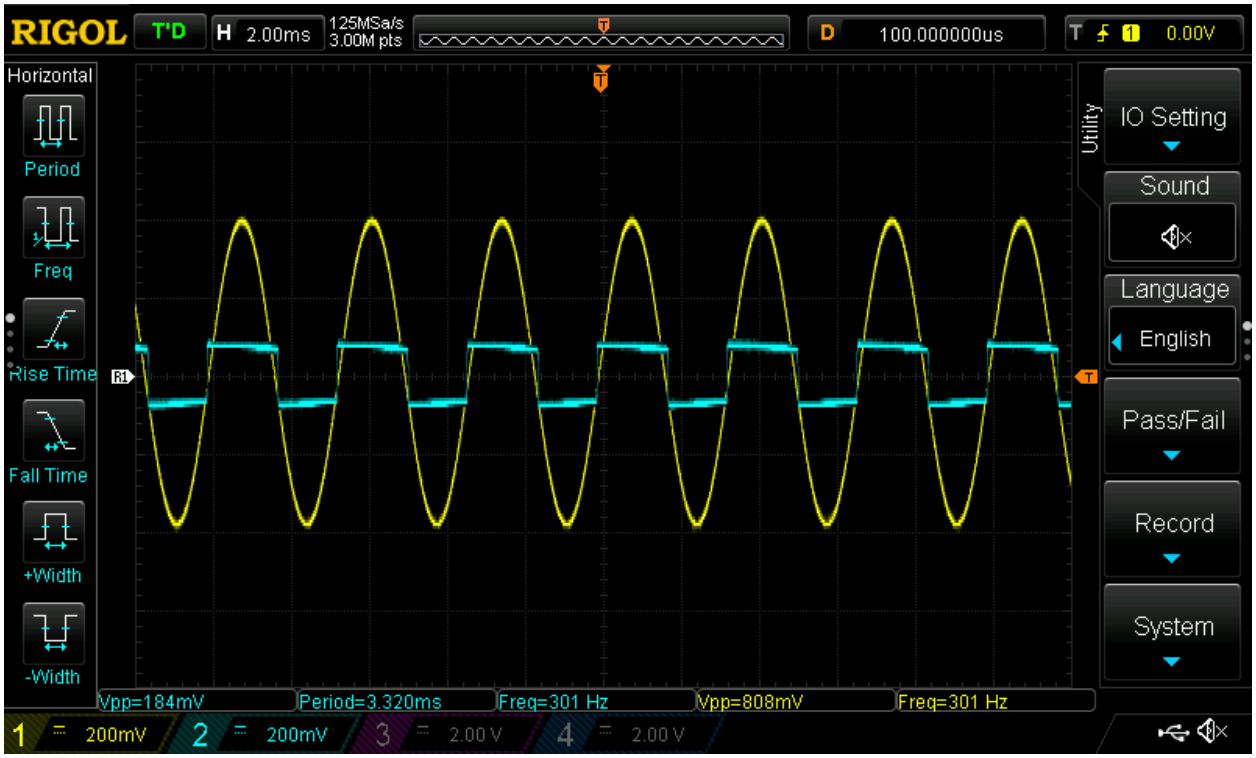


8.6. Volume 50%

Settings:

- Distortion 100%
- Filter 0%
- Volume 50%
- 300Hz input sine wave

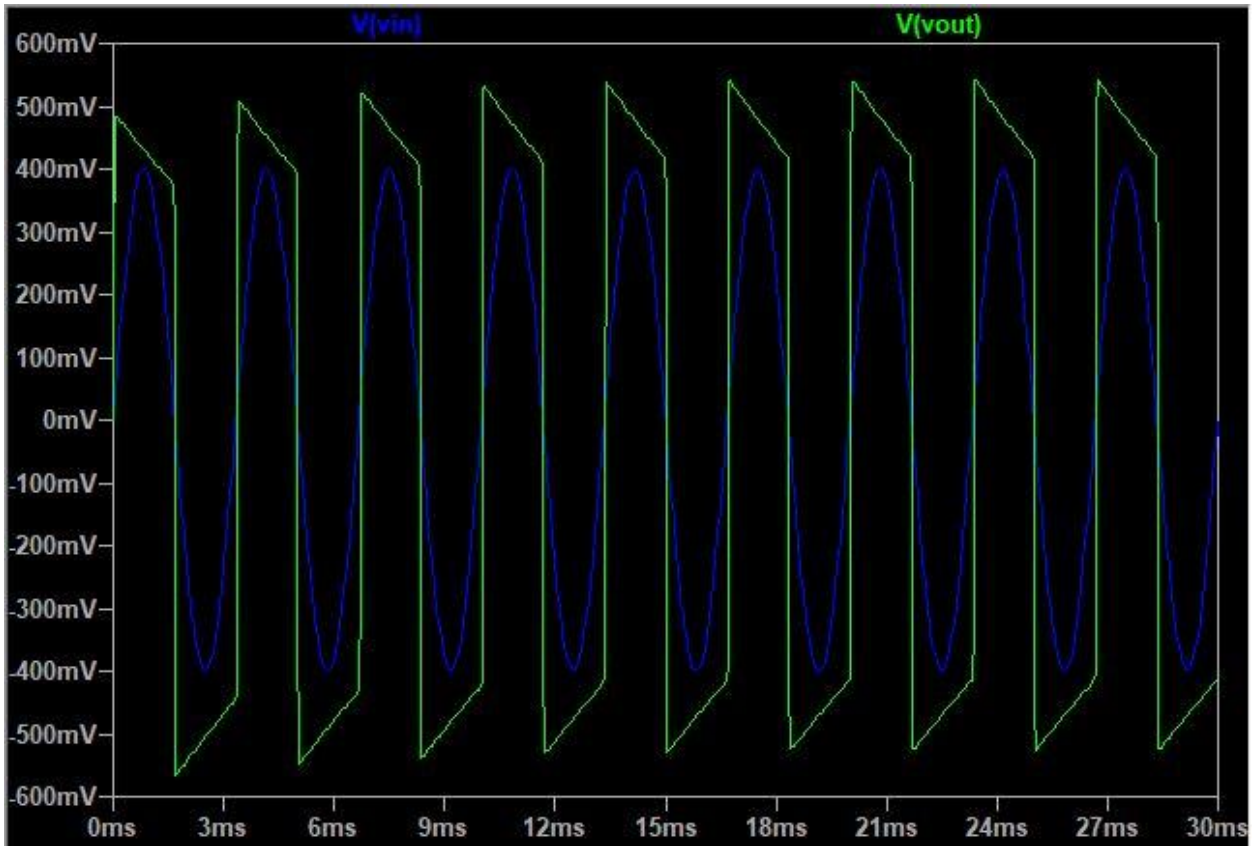

V(vin)
V(vout)
400mV
320mV
240mV
160mV
80mV
0mV
-80mV
-160mV
-240mV
-320mV
-400mV
0ms
3ms
6ms
9ms
12ms
15ms
18ms
21ms
24ms
27ms
30ms

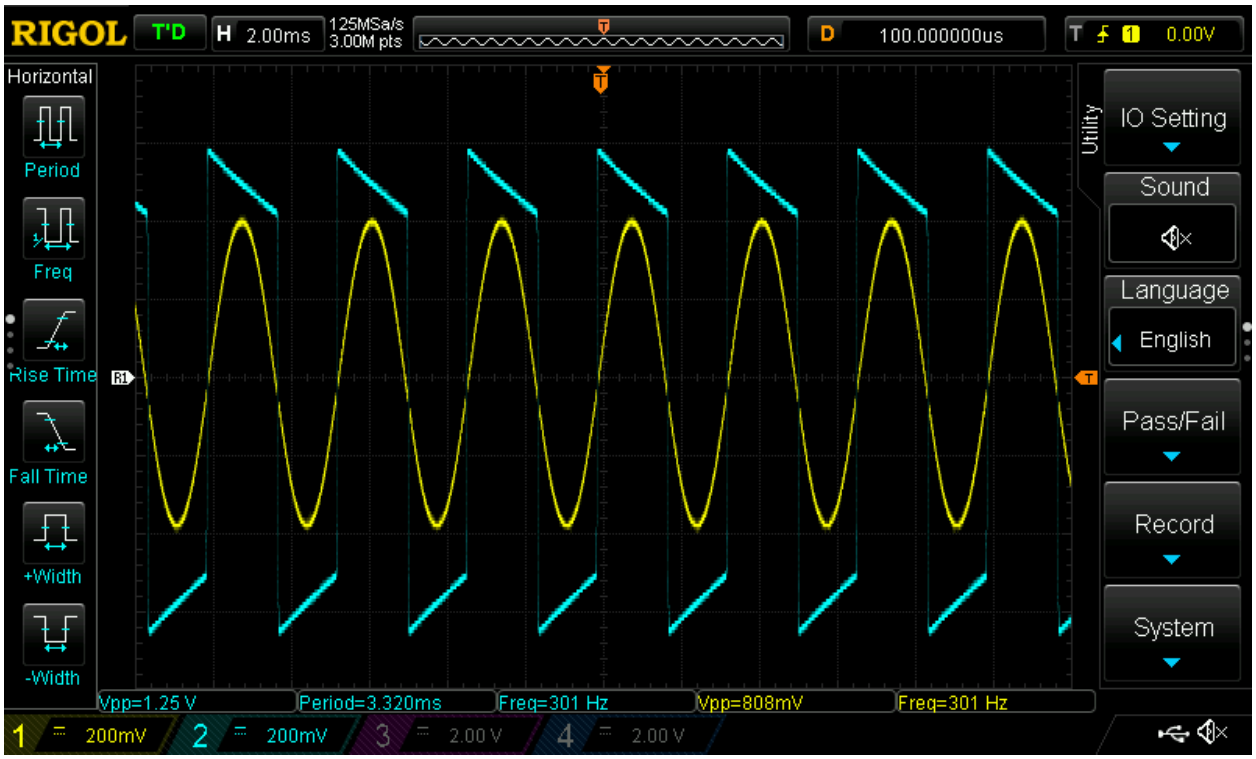

RIGOL
T'D
H 2.00ms
125MSa/s
3.00M pts
D 100.000000us
T 1 0.00V
Horizontal
Period
Freq
Rise Time
Fall Time
+Width
-Width
Utility
IO Setting
Sound
Language
English
Pass/Fail
Record
System
Vpp=184mV
Period=3.320ms
Freq=301 Hz
Vpp=808mV
Freq=301 Hz
1 200mV
2 200mV
3 2.00 V
4 2.00 V

8.7. Volume 100%

Settings:

- Distortion 100%
- Filter 0%
- Volume 100%
- 300Hz input sine wave

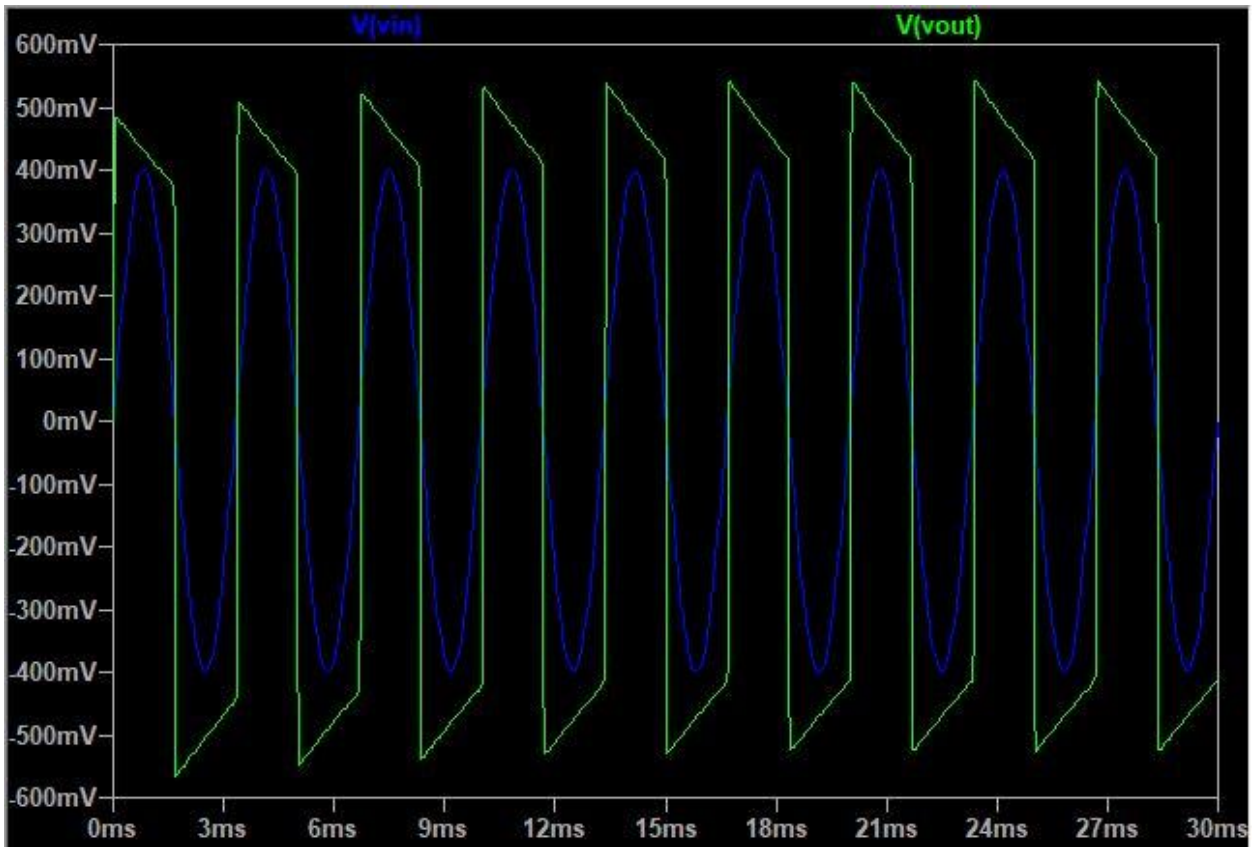


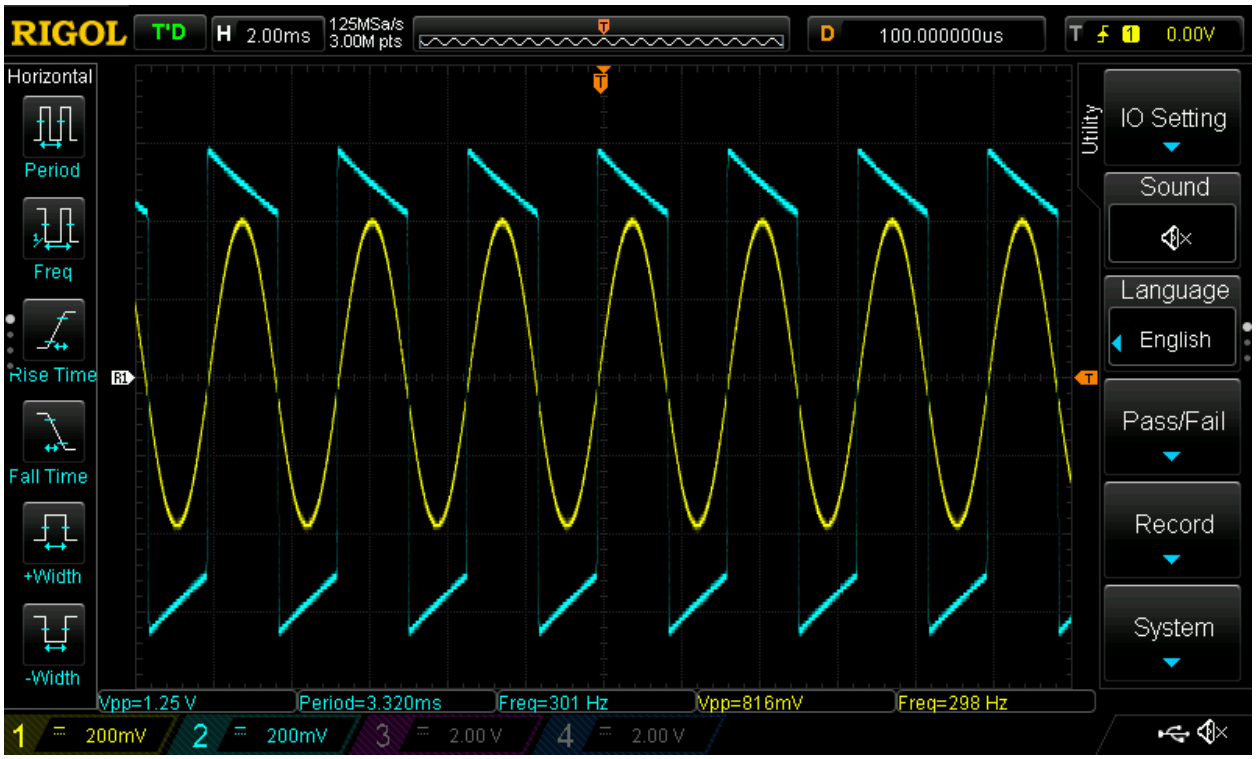


8.8. Tone control 0%

Settings:

- Distortion 100%
- Filter 0%
- Volume 100%
- 300Hz input sine wave

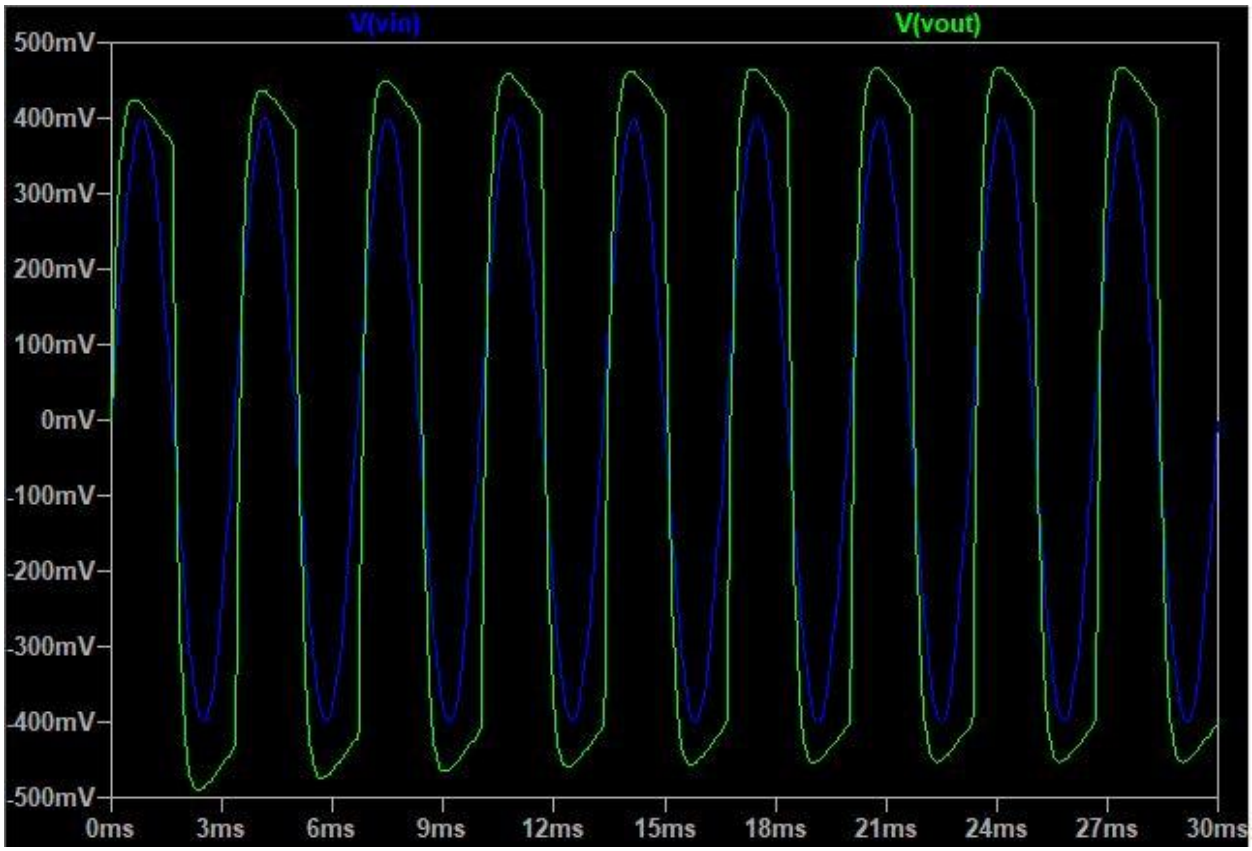

V(vin)
V(vout)
600mV
500mV
400mV
300mV
200mV
100mV
0mV
-100mV
-200mV
-300mV
-400mV
-500mV
-600mV
0ms
3ms
6ms
9ms
12ms
15ms
18ms
21ms
24ms
27ms
30ms


RIGOL
T'D
H 2.00ms
125MSa/s
3.00M pts
D 100.000000us
T 1 0.00V
Horizontal
Period
Freq
Rise Time
Fall Time
+Width
-Width
Utility
IO Setting
Sound
Language
English
Pass/Fail
Record
System
Vpp=1.25 V
Period=3.320ms
Freq=301 Hz
Vpp=816mV
Freq=298 Hz
1 200mV
2 200mV
3 2.00 V
4 2.00 V

8.8. Tone control 50%

Settings:

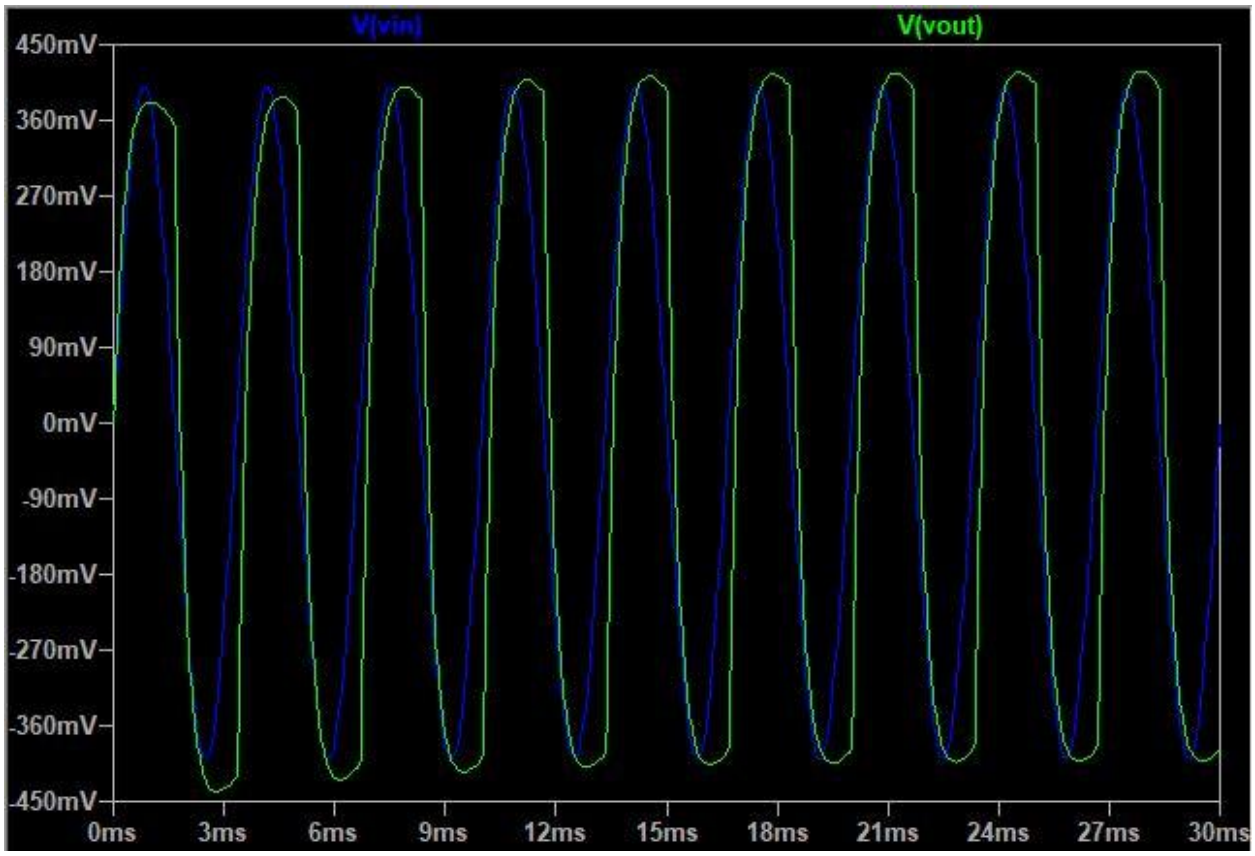
- Distortion 100%
- Filter 50%
- Volume 100%
- 300Hz input sine wave



8.9. Tone control 100%

Settings:

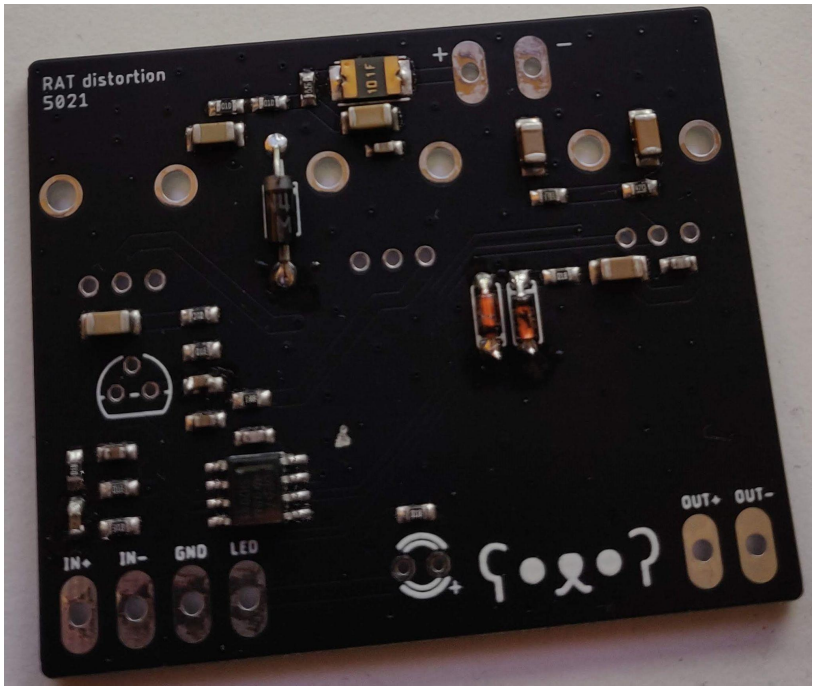
- Distortion 100%
- Filter 100%
- Volume 100%
- 300Hz input sine wave

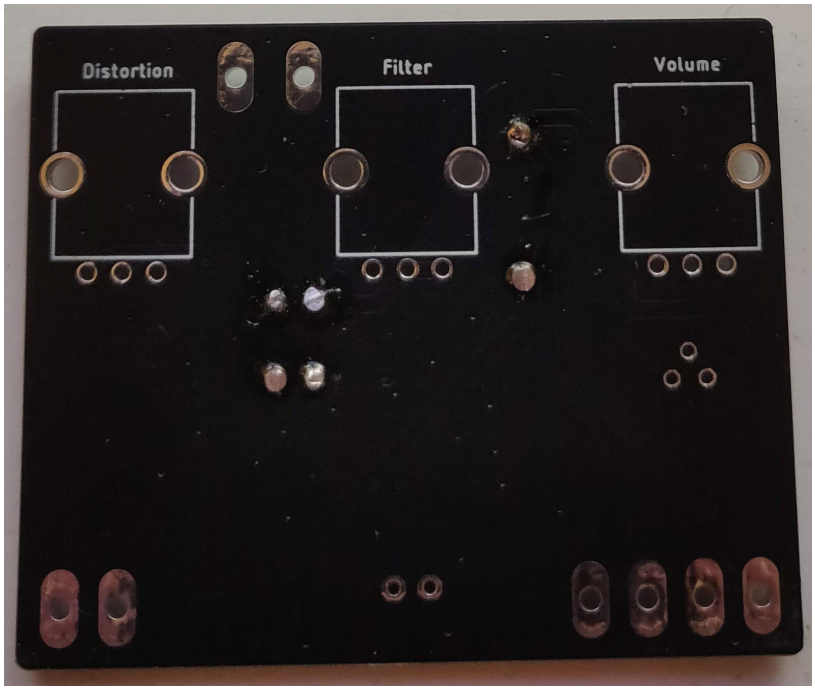

V(vin)
V(vout)
450mV
360mV
270mV
180mV
90mV
0mV
-90mV
-180mV
-270mV
-360mV
-450mV
0ms
3ms
6ms
9ms
12ms
15ms
18ms
21ms
24ms
27ms
30ms


RIGOL
T'D
H 2.00ms
125MSa/s
3.00M pts
D 100.000000us
T 1 0.00V
Horizontal
Period
Freq
Rise Time
Fall Time
+Width
-Width
Utility
IO Setting
Sound
Language
English
Pass/Fail
Record
System
Vpp=944mV
Period=3.320ms
Freq=301 Hz
Vpp=808mV
Freq=301 Hz
1 200mV
2 200mV
3 2.00 V
4 2.00 V

9. Pictures

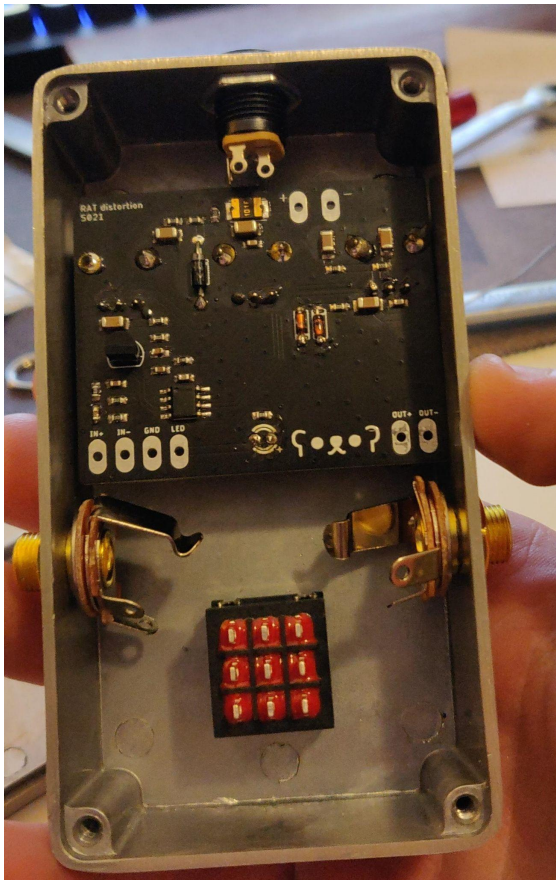
More pictures soon

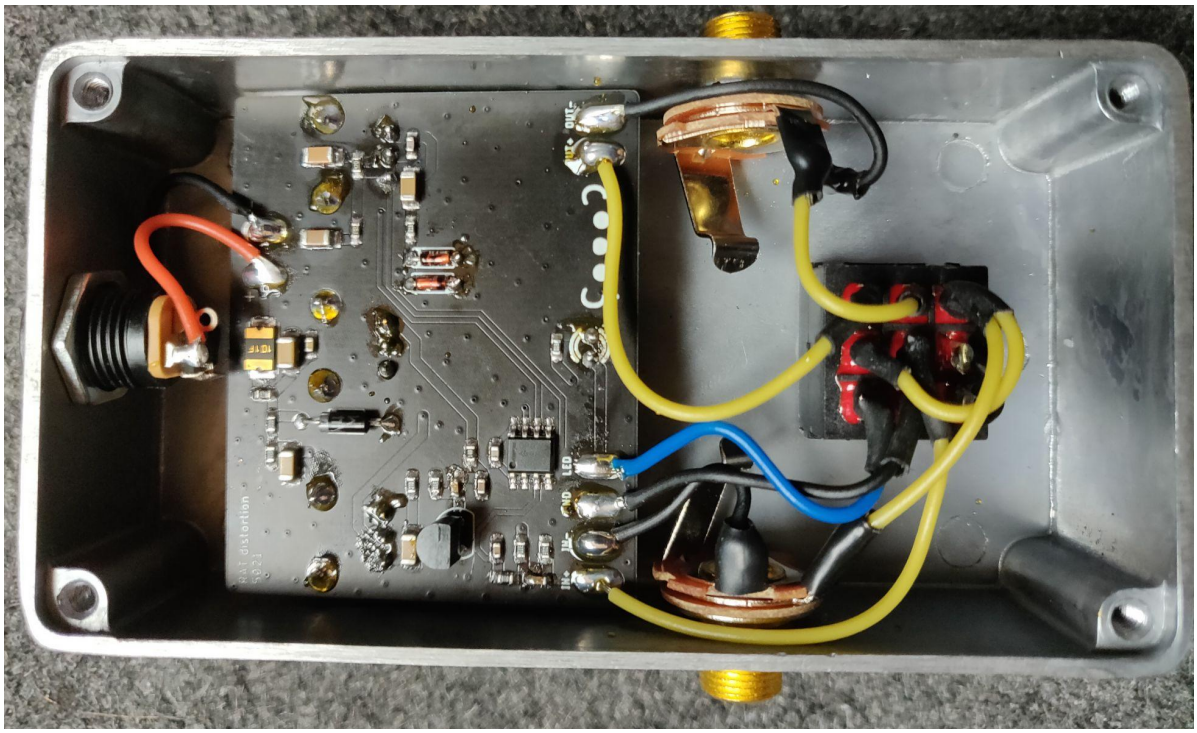





8
8
8
13


8
8
8
12


RAT distortion
S021
IN+
IN-
GND
LED
OUT+
OUT-


OUT-
OUT+
LED
GND
IN-
IN+
RAT distortion
S021


TAP
DIVIDE
FEEDBACK
OUTPUT
INPUT
TAP IN
Canyon
DELAY &
LOOPER
electro-harmonix


FEEDBACK
OUTPUT
INPUT
TAP IN
Canyon
DELAY
LOOPER
electro-harmonix


Blackstar
Canyon
electro-harmonix

10. Used sources

[1] Electrosmash.com. 2013. *ElectroSmash - ProCo Rat Analysis*. [online] Available at: <https://www.electrosmash.com/proco-rat> [Accessed 10 December 2021].

[2] Karlsson, S., 2020. *A Brief Hobbyist Primer on Clipping Diodes*. [online] Guitarpedalx.com. Available at: <https://www.guitarpedalx.com/news/news/a-brief-hobbyist-primer-on-clipping-diodes> [Accessed 15 December 2021].

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