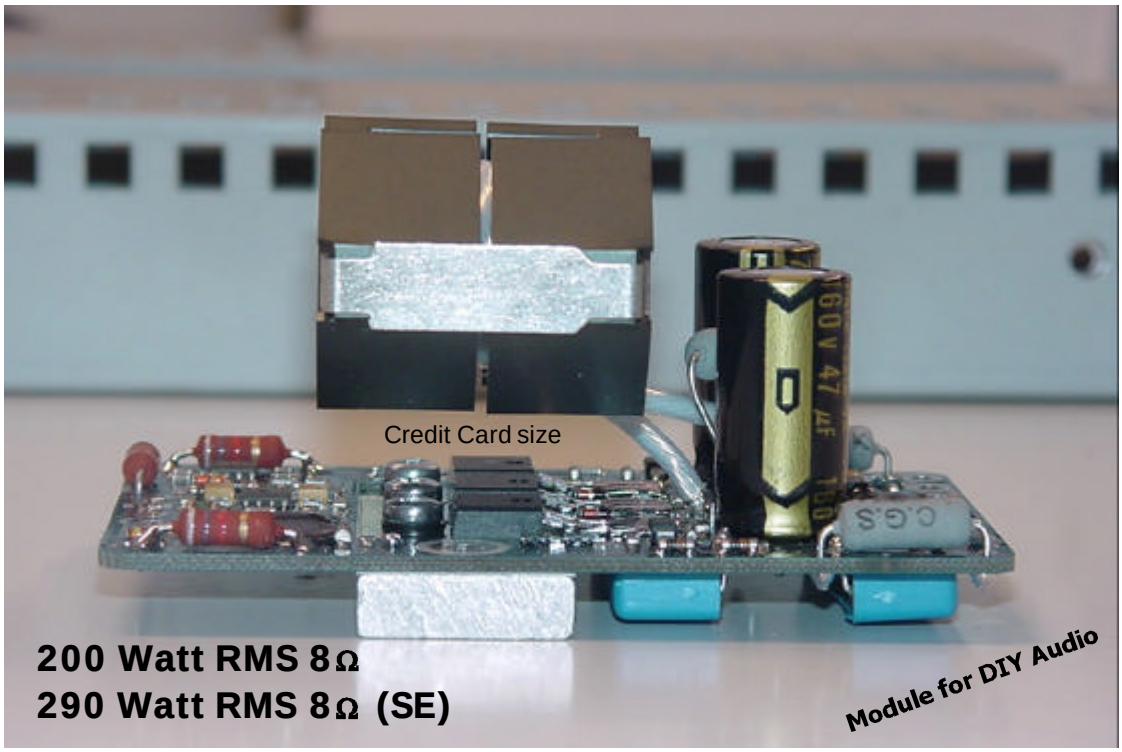
ZAPpulse 2.1
ZAPpulse 2.1 SE

COOKBOOK

PulseField Technology



ZAPpulse 2.1 og 2.1SE *PWM High End Digital Audio Power Amplifier module. Balanced and unbalanced line input, Short Circuit Protection, 4 layer circuit board and controlled switching slope ensure minimal EMC emissions. Sound quality comparable to the best available analog power amplifiers.*

ZAPpulse 2.1 *uses supplies of 35 - 60 V DC and produces 200W RMS@8 Ohms, and up to 800 W RMS@2 Ohms.*

ZAPpulse 2.1 SE *runs on 35 - 72 V DC and produces 290 W RMS@8 Ohms and more than 1050W RMS@2 Ohms. 2.1 SE is equipped with Black Gate VK.*

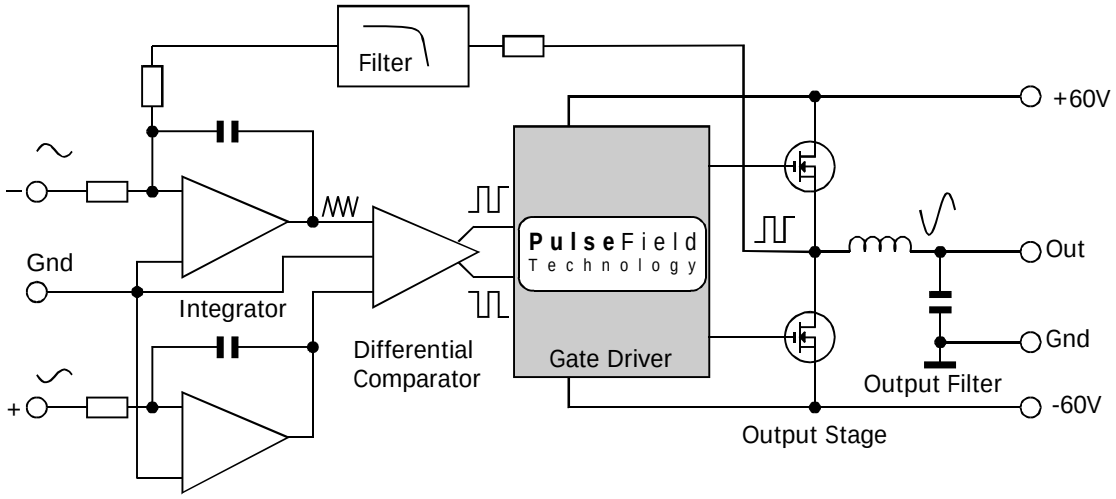
Dynamics, Soundstage, natural musical perception, clarity, warmth!

Content.

Further information: www.lcaudio.com

Principle of Operation.

In a conventional amplifier the input signal is amplified through various analog stages to a progressively higher amplitude. In the final stages of the amplifier, the output stage, high current capability is added to enable the amplifier to drive loudspeaker loads. When current is drawn out of the output stage to the load, heat is dissapated in the output stages, since the load current multiplied with the voltage drop over the output device gives a power value (of average 60% of the max. output power) that needs to disappate in heatsinks. 60% is not the power loss at maximum output power, but the average heat disappated at various output power levels (except very small levels below 1W). So a 100 Watt amplifier will averagely need to disappate 60 Watts power into heatsinks. The ZAPpulse operates in a different way, the output devices are either on or off with no significant voltage drop, so even when the load draw large amounts of current, there is only minimal power to be disappated. To control the signal amplitude, the pulse width of the output square wave is controlled very accurately.



After the output devices the square wave need to be filtered with a choke and capacitor, to get an analog output signal without noise that can be fed to the loudspeakers. The choke and capacitor's quality is paramount in order to get a good sound quality, so we use an oversized (1.5 kW) ultra high speed ferrite core with silver conductor and TEFLON insulator. This choke has a very low impedance of only 5 milli Ohms, and allows for a good damping factor in any speaker load. To get an output signal of say 30V, the output devices are made to switch high 75% of time, and 25% of time low. In this case the Pulse Width is 75%, since the V+ - V- is 120V, the output voltage seen from V- is 75% of 120V = 90V. 90V on top of -60V is 30V, as wanted in our example. Operating from +60V to -60V allows for any output voltage in this range, including 0V. Thus a total DC coupled system for highest possible sound performance. Pulse Width Modulation is often shortened to PWM. A very important stage in a PWM amplifier is the modulator, that can be made i various ways, with different properties. We have selected and optimized the balanced integrating type, as it is highly stable, and has very low distortion.

More ZAPpulse 2.1 Technology!

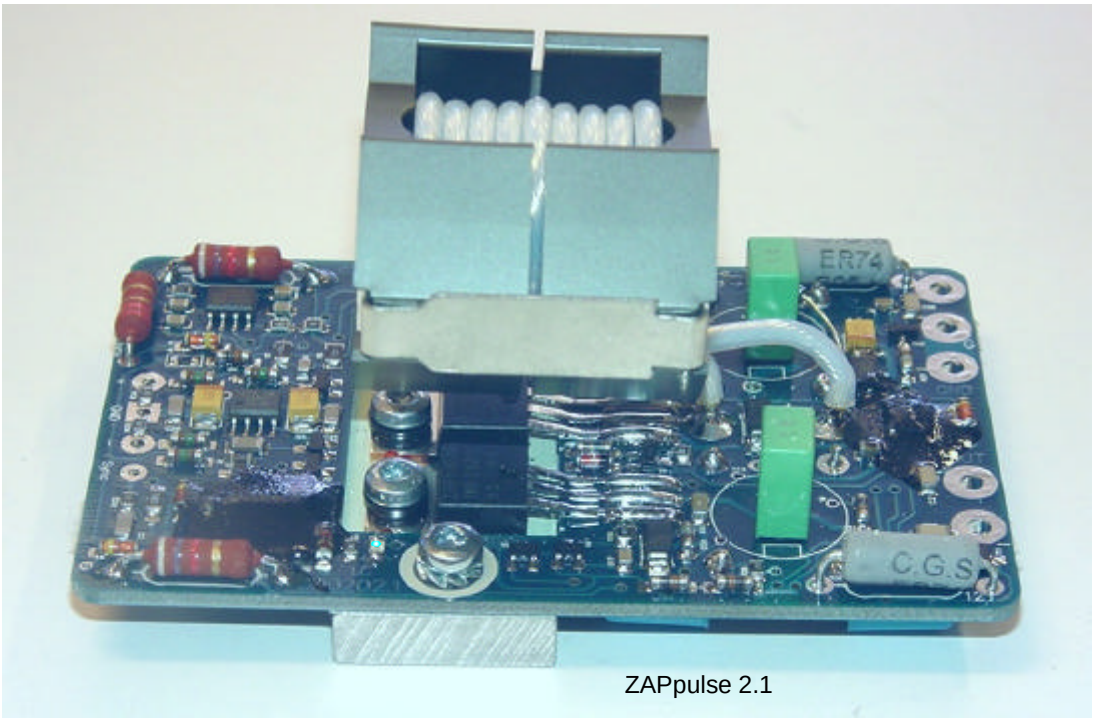
The heart of the ZAPpulse amplifier is a balanced integrating PWM modulator. It basicly integrated the DC level of on switching cycle of the output stage, including any switching noises, slope differences etc. Then this value is compared, and corrected in the next switching cycle to create an output signal of exactly 0 Volt. This correction is performed every switching cycle, which is about 500.000 times per second.

The input signal is injected directly into the integrator to keep signal paths ultra short. No signal conditioning, such as DC blocking, HF blocking or other limiting factors are present on the ZAPpulse module. So if this is required by your application, you have to add these functions outside the module. When signal is applied to the input, the integrator no longer corrects the output signal level to 0 Volts, but rather to the signal curves.
The feedback group delay is kept very low, only around 2 uS, to allow for TIM free operation. The analog integrating feedback loop has a lower group delay of any completely digital (A/D based) feedback loop. And since output switching noise products are the same no matter the modulator type, the analog feedback loop gives a much better rejection of noise products than a true digital approach. It's all about speed, and how fast the noise can be cancelled.

The output square wave has a base frequency of typ. 500 kHz, and rise times of some 10.000 V/uS. The slopes are minimised to around 50nS to keep switching losses low at heavy speaker loads. However at low signal amplitudes the main power loss comes from capacities in the MOSFET's, so transitions are slowed to reduce EMI, noise and idle loss. This is controlled by the PulseField circuit in the Gate driver.

A simple rule says that at no signal, a ZAPpulse loses some 9.5 Watts power to capacities in the MOSFET's, and at full power it loses another 9.5 Watts to serial resistance. So at 500 W out you only have to disappate around 19 Watts to the heat sinks.

One great advantage PWM amplifiers have over conventional analog amplifiers is, that in the analog amplifier it is difficult to avoid the harmonic distortion products, that are signal dependent, and therefore interacts with sound quality. In the PWM amp, the distortion is non-harmonic, and inde-pendent of signal contents. In sonic performance properties this translates to the PWM amplifiers exceptional ability to expand the sound stage with added sound level. An analog amplifier would typically collapse the soundstage at higher levels, depending on the size of the power supply (why we have huge power supply banks in all our analog amplifiers). The PWM will play with wide and deep sound stage at any lisytening level, even with a very (almost too) small power supply. We have made tests with a 2 x 250 W RMS ZAPpulse amp, running with only two 2200 uF 100V main caps. And it still has plenty of bass control, definition, width and depth. Opportunities for interesting experiments in this field are obvious.

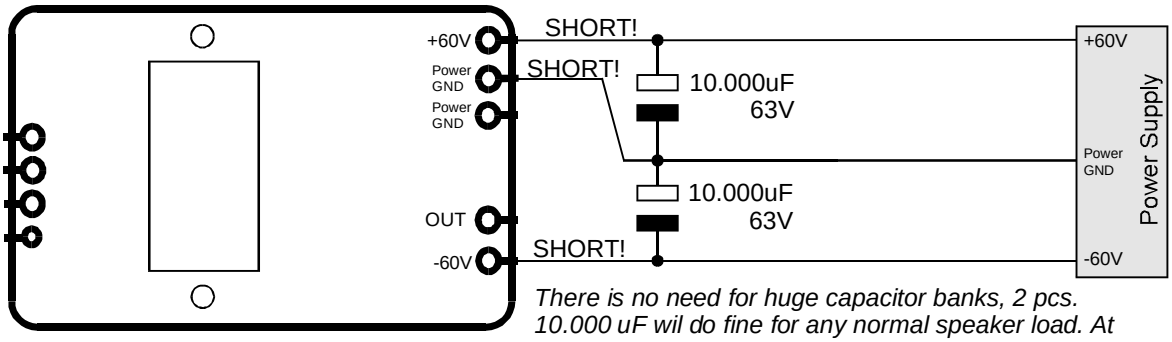


ZAPpulse 2.1

Connection of Power Supply.

To make ZAPpulse 2.1 work, simply connect a typical Audio Power Supply of +/-35V to +/-60V (+/- 72V for SE version). The output power depends on the voltage of the power supply. The 2.1 standard version uses 63V capacitors, on the board, while the 2.1 SE uses 160 V caps. This is why the SE can be made to deliver much higher powers than the standard modules. In the standard version, the sound quality of the main caps must be considered.

The midrange and treble sonic properties of these caps, will interact with the overall sound performance of the amplifier, so we recommend using very high quality caps with standard modules. With the SE modules the mid and high frequency performance is fixed at the highest level by the Black Gate VK caps (47 uF 160V). So PSU caps only need to have good bass props. Always use short and heavy wire between PSU caps and modules (< 4-5 inches).



There is no need for huge capacitor banks, 2 pcs. 10.000 uF wil do fine for any normal speaker load. At 2 Ohms load, maybe 2 pcs. 22.000 uF will work perfectly. All energy in the capacitor bank is translated almost lossless to audio power. Practical experiments show that even with only 2200uF these modules will deliver incredible high performance Audio sound. (8 Ohms speakers).

Correlation of Output Power and Supply Voltage.

The Output power can be calculated as a result of the max. signal amplitude, which depends on the supply voltage. At +/- 60V Supply Voltage the amp can ideally deliver 120 Vpp. To calculate the output power we need the RMS value, which is simply 120 / 2pi = 120 / 2,82 = 42,6 Vrms (in this example).
Output power is then calculated using Ohms Law:

$$P = \frac{U^2}{R}$$

P = Output Power RMS
U = RMS Voltage (42,6)
R = Speaker Impedance (8)

In this example 223 watts RMS.

This was ideal values, in ZAPpulse the practical values are corrected with a serial loss of 1 - 3 VDC depending on load impedance (1 V @ 8 Ohms).

At +/- 60 VDC you will get a practical output power of: some 210 Watts RMS.

See below for output powers at other transformer voltages, and load impedances.

Bottom table shows bridge mode ZAPpulse modules operating at very high power!

Transformer Voltage	DC Voltage after Rect.	P out in 8 Ohms	P out in 4 Ohms
2 x 24 V AC	+/- 32 V DC	60 W	106 W
2 x 27 V AC	+/- 36 V DC	78 W	137 W
2 x 33 V AC	+/- 45 V DC	119 W	222 W
2 x 36 V AC	+/- 49 V DC	144 W	266 W
2 x 40 V AC	+/- 55 V DC	180 W	340 W
2 x 42 V AC	+/- 58 V DC	200 W	380 W
2 x 45 V AC	+/- 62 V DC	230 W	438 W
2 x 50 V AC	+/- 69 V DC	286 W	548 W

You can also bridge two ZAPpulse modules to get a much higher output power. See how later in this booklet.

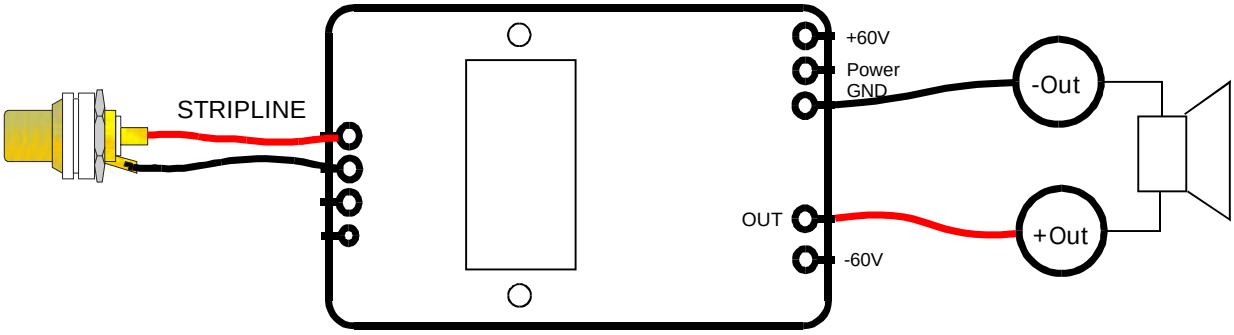
Transformer Voltage	DC Voltage after Rect.	P out in 8 Ohms	P out in 4 Ohms
2 x 24 V AC	+/- 32 V DC	219 W	397 W
2 x 27 V AC	+/- 36 V DC	286 W	526 W
2 x 33 V AC	+/- 45 V DC	448 W	837 W
2 x 36 V AC	+/- 49 V DC	542 W	1019 W
2 x 40 V AC	+/- 55 V DC	682 W	1291 W
2 x 42 V AC	+/- 58 V DC	758 W	1439 W
2 x 45 V AC	+/- 62 V DC	879 W	**note**
2 x 50 V AC	+/- 69 V DC	1100 W	**note**

note: We can NOT guarantee the modules to operate safely with this load.

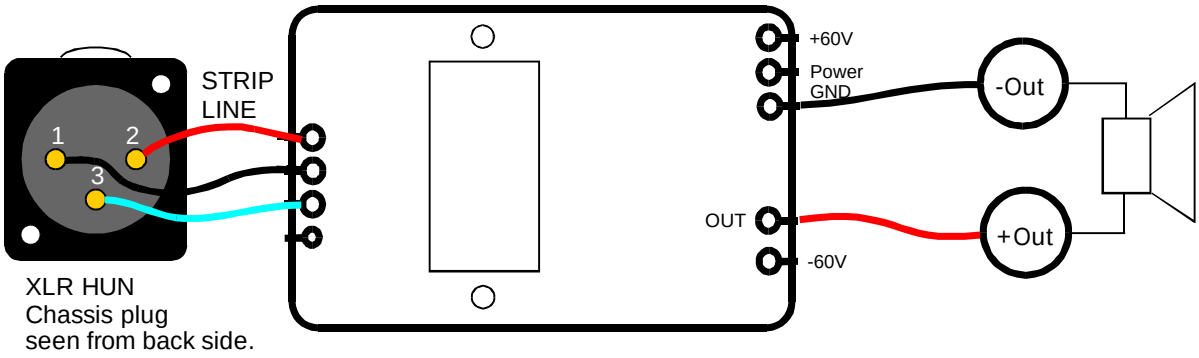
Input- and output connections.

Different input- and output options shown.

Unbalanced input connection.



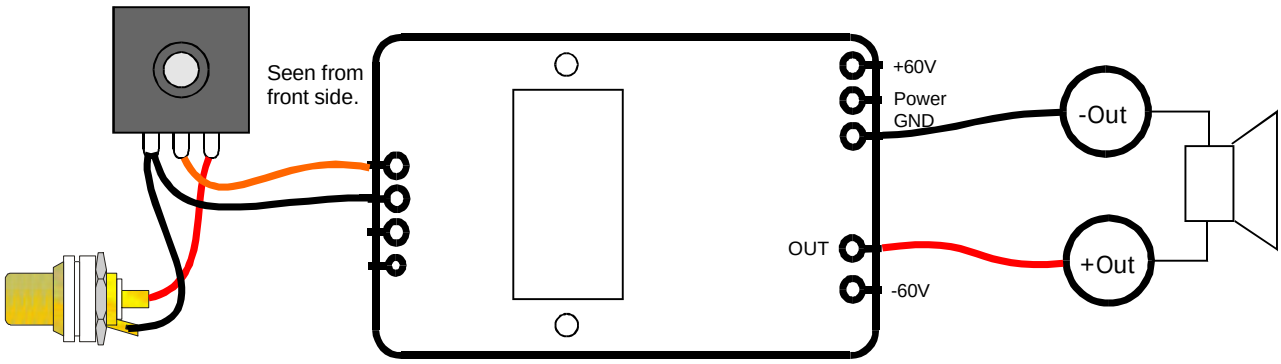
Balanced input connection



If you want to ensure stable operation of your amplifier, then avoid input wires to run along with speaker wires, or wires from the transformer (both primary and secondary wires).

Passive Volume control

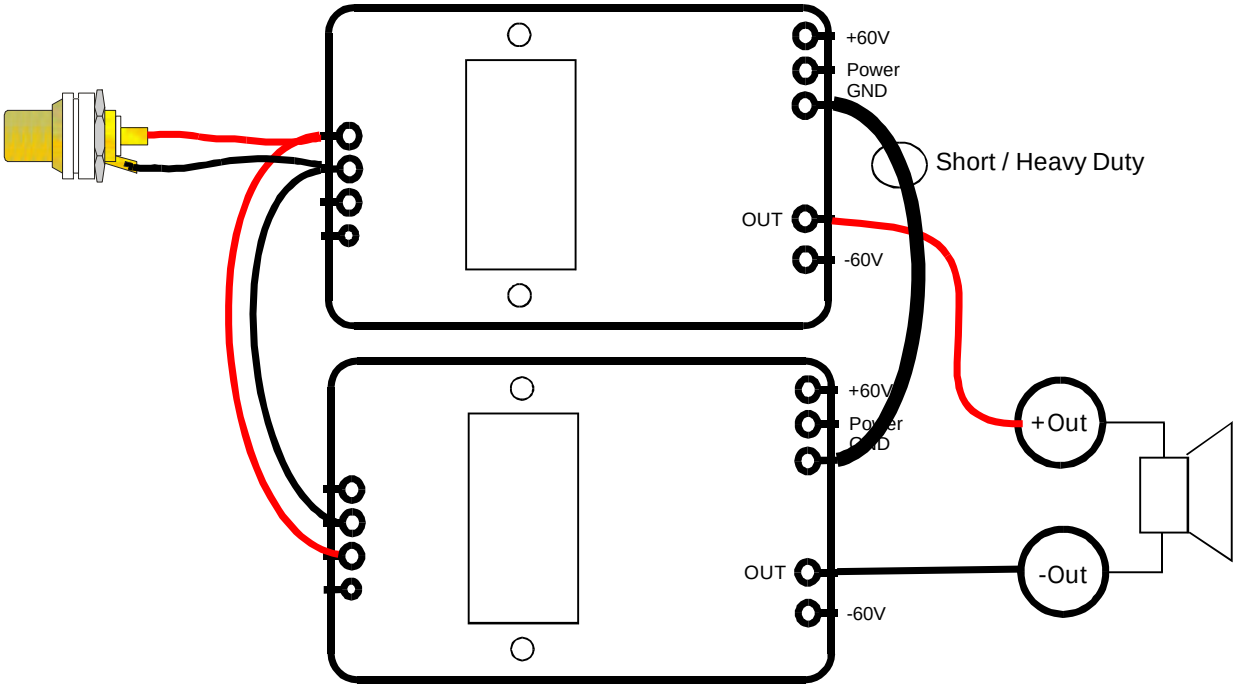
Potentiometer 10k log.



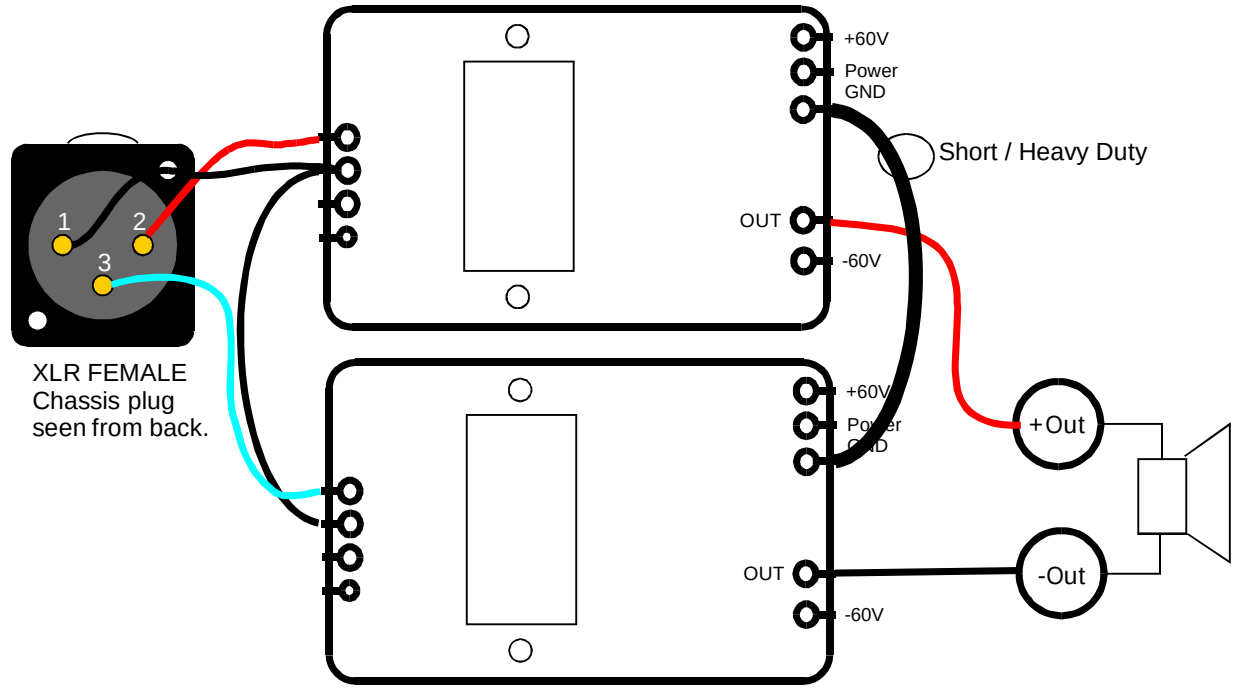
Bridging.

Thanks to the tru balanced input circuits, it is very simple to bridge ZAPpulse modules and achieve extreme high output powers. Suitable for PA systems and PRO subwoofers.

Unbalanced Input Signal.



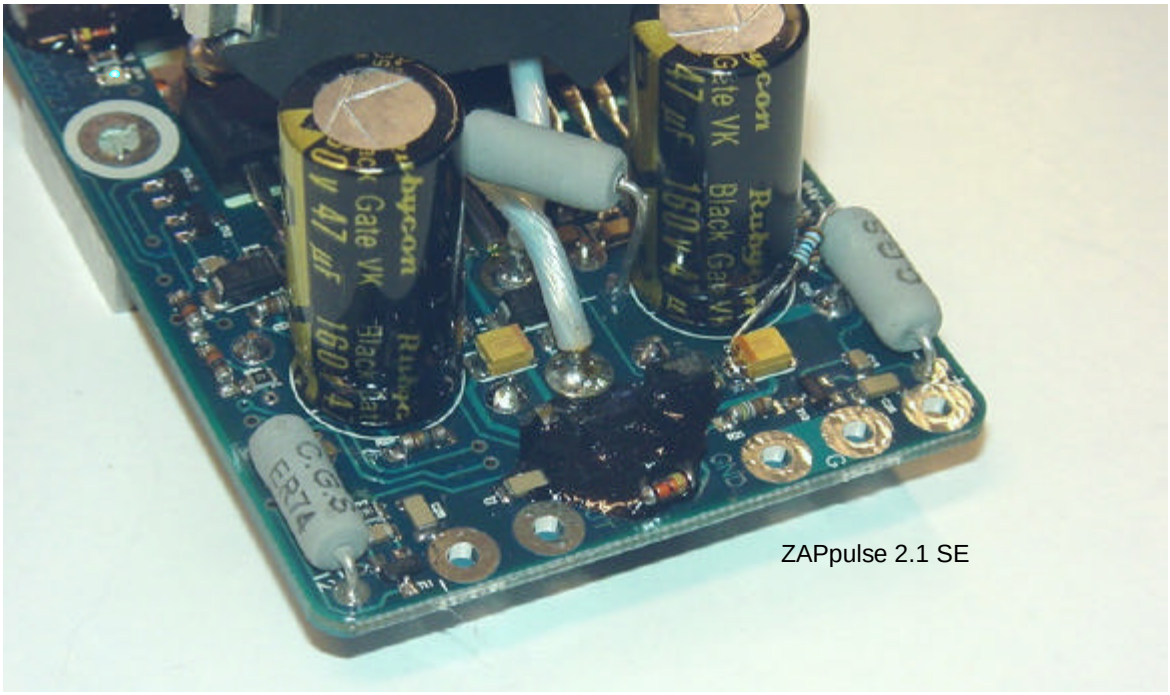
Balanced Input Signal.



Considerations on Switching Frequency.

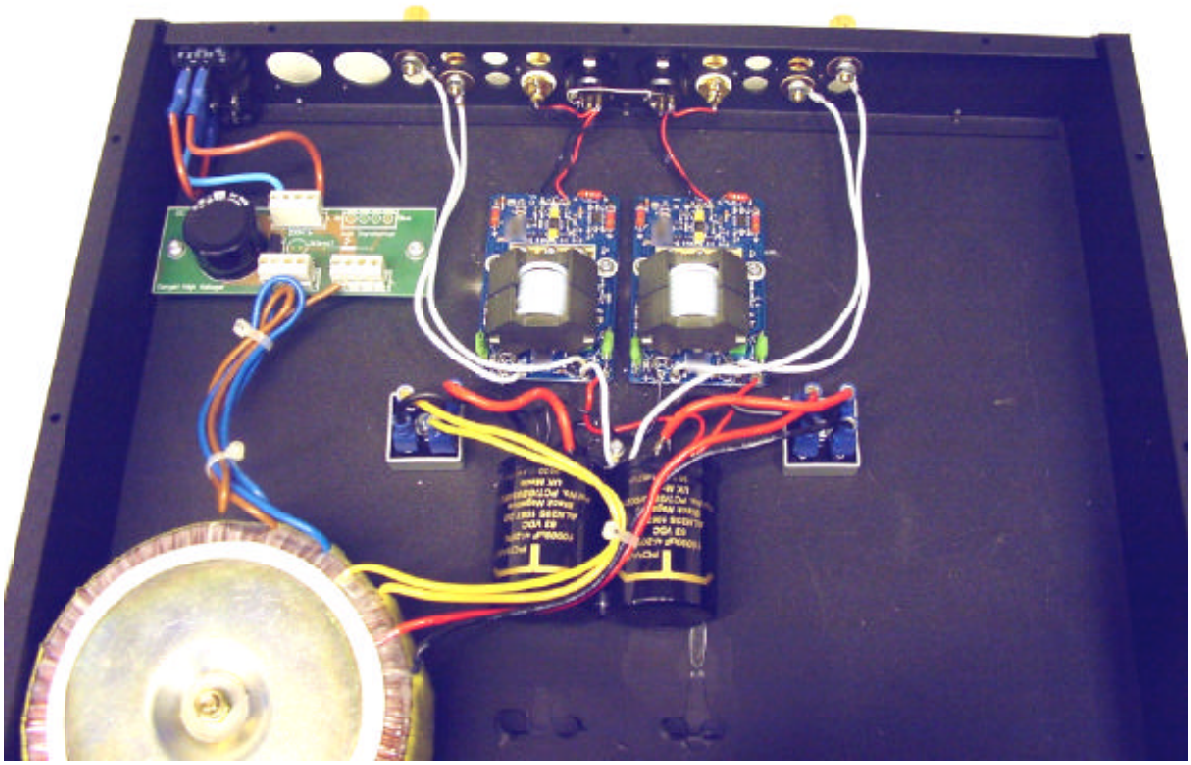
The Switching frequency is the rate of which the output stage switches high and low with various duty cycle to create the Audio output signal. This frequency has no direct connection to the frequency bandwidth of the amplifier, although there are some dependencies. The Bandwidth of the amplifier is mainly limited by the output choke, filter cap and speaker load impedance. Typically ZAPpulse 2.1 will have a linear bandwidth to around 180 kHz for full power.
The switching frequency can be controlled or as normally left in the free running mode. In this mode the module will run at it's natural switching frequency of around 490 kHz.

In some cases it is useful to control the switching frequency with an external oscillator, and this is possible by simply applying a TTL or sinusoidal frequency of 250kHz - 1 MHz to the Sync. input (see later). If you have 4 - 5 - 8 channels in one enclosure, switching noise can be reduced this way. Also resolution in the treble range may be slightly improved, by running the amplifier at 1 MHz, instead of 490 kHz. You may also want to experiment with a completely syncronized audio system, where a 1.05 MHz signal is derived from a central 16.9 MHz clock, that also controls your D/A converter and CD player transport. ***NOTE Frequencies below 250 kHz or above 1 MHz may damage the module permanently.***



ZAPpulse 2.1 SE

Through hole plated wire terminals allow for stable and easy connection of wires up to 12 AWG / 2.5 sqr. These platings connect directly to ground and power planes with copper tracks as wide as the entire board. So there is practically no loss in the circuit board. The Black Gate VK caps on this 2.1 SE module enforces perfect midrange and treble reproduction independant of Power Supply Cap's sound quality.



This photo shows the simplicity of a complete amplifier based on ZAPpulse modules. The board in the upper left corner is a DC filter that prevents the transformer from humming in case there is DC on the mains grid. As can be seen there are both balanced and unbalanced input plugs connected to this amplifier, and it is a viable option. So just plug in the signal type you wish to use. In this amp we have used the T-Network caps from BHC Aerovox, they are good but very expensive. In case you want to use cheaper caps, we recommend changing to ZAPpulse 2.1 SE, as they are virtually independent of the caps quality.

ZAPpulse 2.1 SE 500 Watt RMS@4Ohms

A ZAPpulse 2.1 module has exactly the same footprint as a normal credit card.

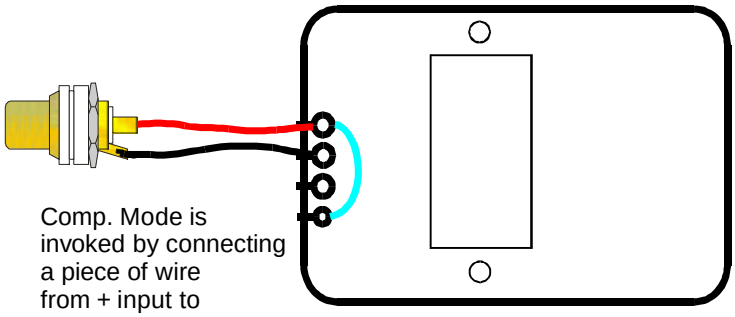
Compensated Mode

The output filter of ZAPpulse 2.1 made with a choke and a cap, is not only a 12dB / Octave filter, but at the criotical frequency, it is also a suction network. This frequency is around 150 kHz, and will cause a signal peak of around 12-14 dB @ 8 Ohms load. (6 dB @ 4 Ohms). Completely out of audible range, but enough to cause some tweeters to sound sharp, even if ZAPpulse has a ruler straight frequency response to 70 kHz.

It is impossible to remove the resonance completely, but you can simply compensate for the peak, as shown below. With this small compensation, the frequency response will be straight from DC to some 180 KHz within 3-4 dB. (See frequency curves on page 13.)

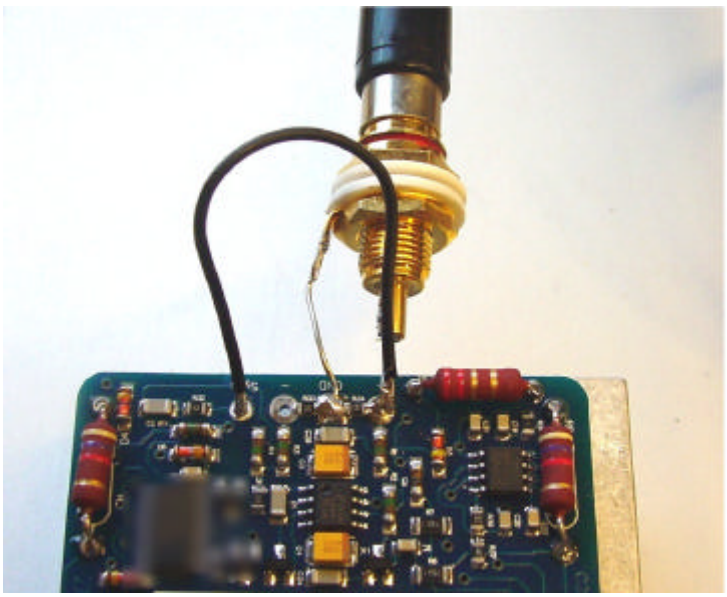
So in case you experience a little sharpness in the treble, this simple compensation may be the solution.

You can alter the compensation or even make 1st order low pass filters by connecting a capacitor from + input to - input. (Resistor is 2k0).



Comp. Mode is invoked by connecting a piece of wire from + input to Sync. Input. (Blue).

You may also connect a 1n cap from + input to - input then you can chose the preferred type of cap.



Technical data

Absolute Maximum Ratings

Operating Temperature .....0 - 70°C

Storage Temperature .....-10 - 70°C

Supply Voltage Power .....+ and - 63 V

Supply Voltage Power (2.1 SE) .....+ and - 75 V

Input Voltage .....+/- 15 V

Output Current DC .....+/- 22 A

Repetitive Output Current <100mS ..... +/- 44 A

LEGAL and WARRANTY NOTICE
Use of this product is at own risk and liability. No legal liability is assumed by producer, distributor, wholesaler or any other staff or associate of L C Audio Technology. Warranties cover any failure, occuring when product is used within maximum ratings bounds, and as shown on application notes.
If product is stressed beyond these limits, the warranty is void.
We direct your attention to high EMC levels of this product may affect other electronic systems, such as pacemakers, life support systems in vicinity, TV and radio reception equipment, computers, and other electronic equipment.
In such cases where any disturbances occur, the risk and damages are fully assumed by the user of the product.
Warranties do not cover any other item than the product itself, even in cases where failure can be traced to the producer.

DC Characteristics

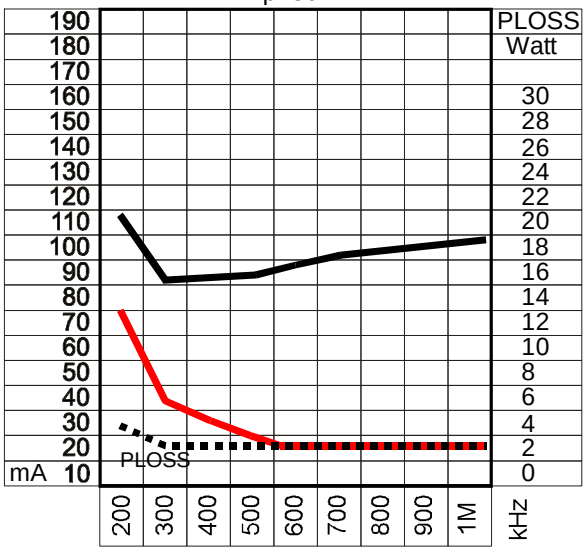
Symbol	Parameter	Condition	Min	Typ	Max	Units
Vp	Main Supply Voltage		35		60	Volts
Vp	Main Supply Voltage	2.1 SE	35		72	Volts
Ip0	Main Supply Idle Current	Fsw=500kHz 45V	-	38	60	mA
Ip0	Main Supply Idle Current	Fsw=500kHz 45V	-	-110	-142	mA
Ip0	Main Supply Idle Current	Fsw=500kHz 60V	-	50	74	mA
Ip0	Main Supply Idle Current	Fsw=500kHz 60V	-	-120	-160	mA
Zin	Signal Input Load		2,00	2,03	10	kOhm
Zout	Output ESR	Vp- << Vo << Vp+		6	10	mOhm

AC Characteristics

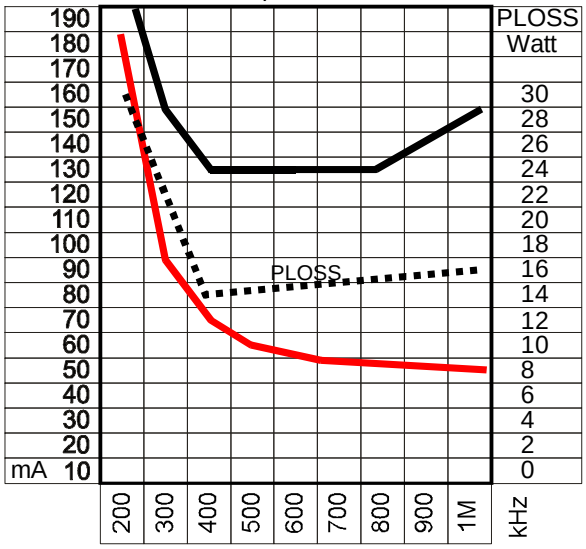
Symbol	Parameter	Condition	Min	Typ	Max	Units
G	Voltage Gain		40	41,2	43	
GdB	Gain dB		32	32,3	32,7	dB
IN	Equivalent input noise	BWL 20-20.000 Hz		200		uV
Fmax	Signal Bandwidth	8 Ohms +/-3dB	80	91	100	kHz
Fmax	Signal Bandwidth	8 Ohms +0-1dB	60	62	70	kHz
Fmax	Signal Bandwidth, Comp.	8 Ohms +/-4dB	160	180	200	kHz
LD	Load Impedance	20 - 20.000 Hz	2	8	32	Ohms
LDD	Load Impedance	5 - 100.000 Hz	2	8	16	Ohms
THD	Total Harmonic Distorsion	BWL 20-20.000 Hz		0,03	tbd	%
OD	Output Damping Factor	8 Ohms	200	250	320	

Typ. Power Consumption

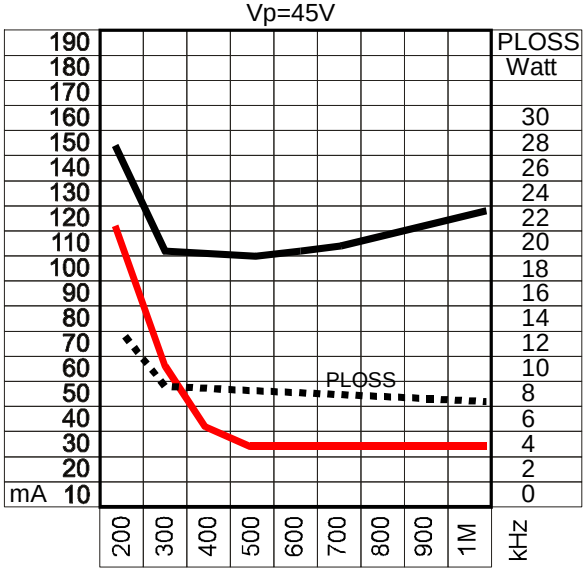
Vp=30V



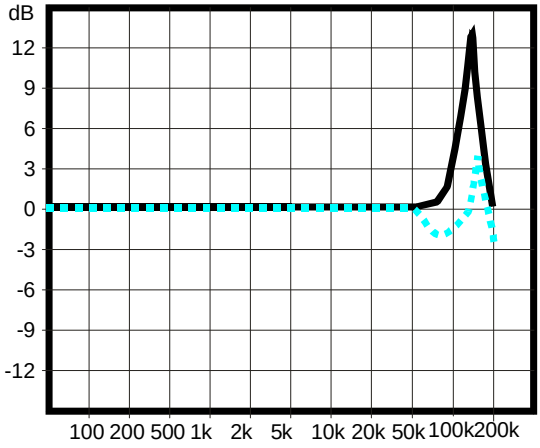
Vp=75V



Vp=45V

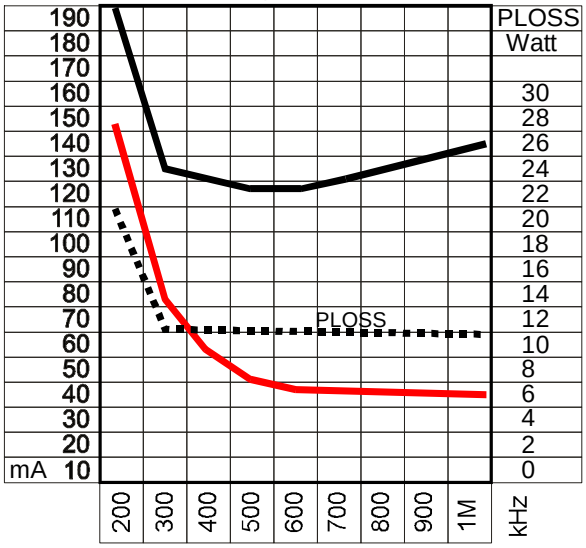


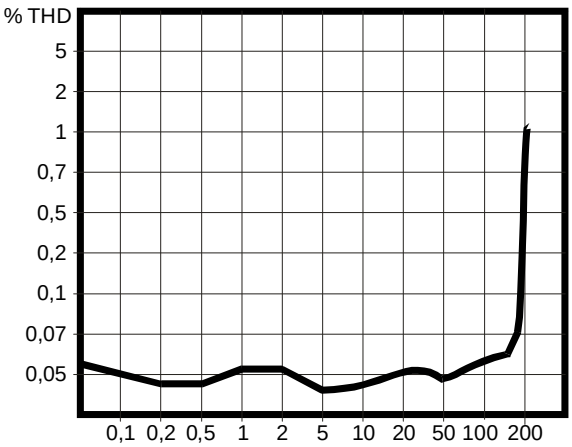
Frequency Response / THD



Frequency Response
(dotted is Comp. Mode)

Vp=60V

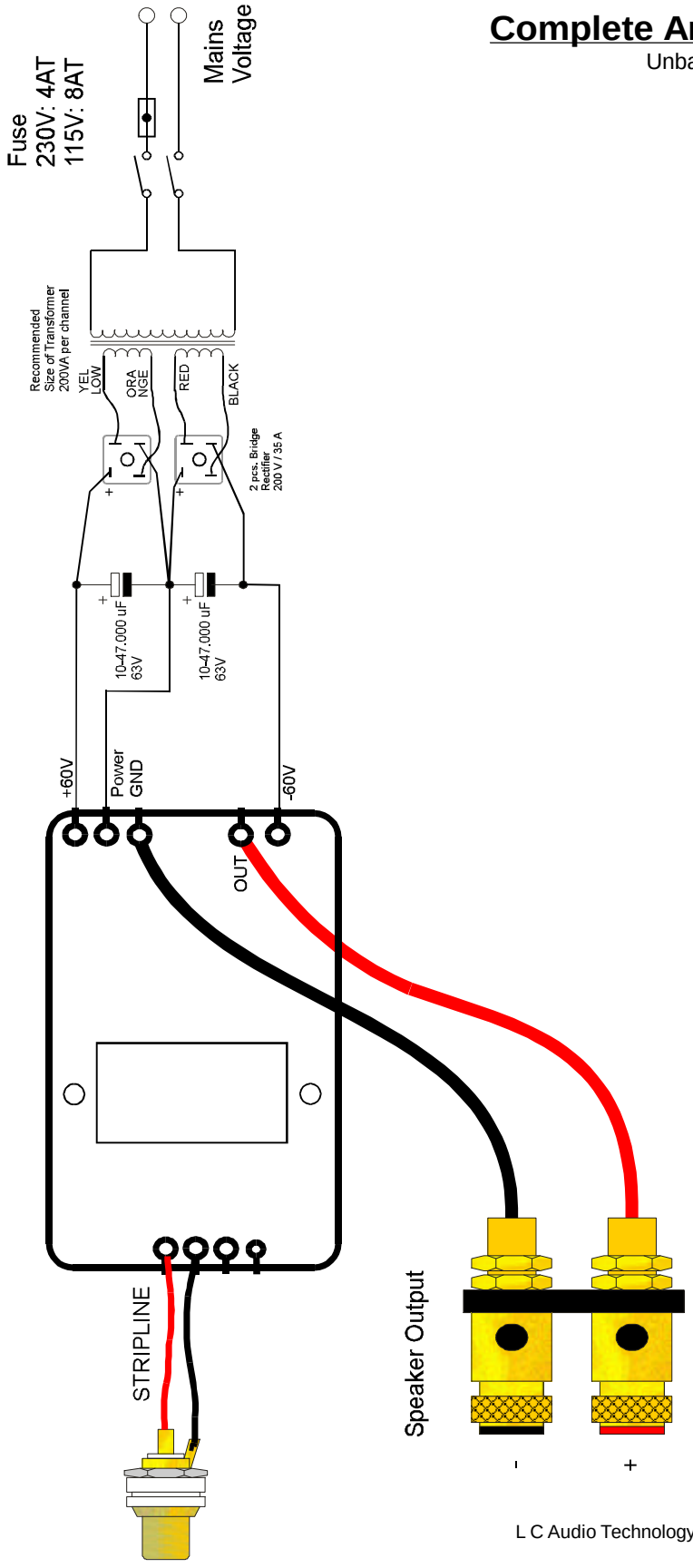




THD + N vs. Output Power 1 kHz 8 Ohm

Complete Amplifier

Unbalanced Input



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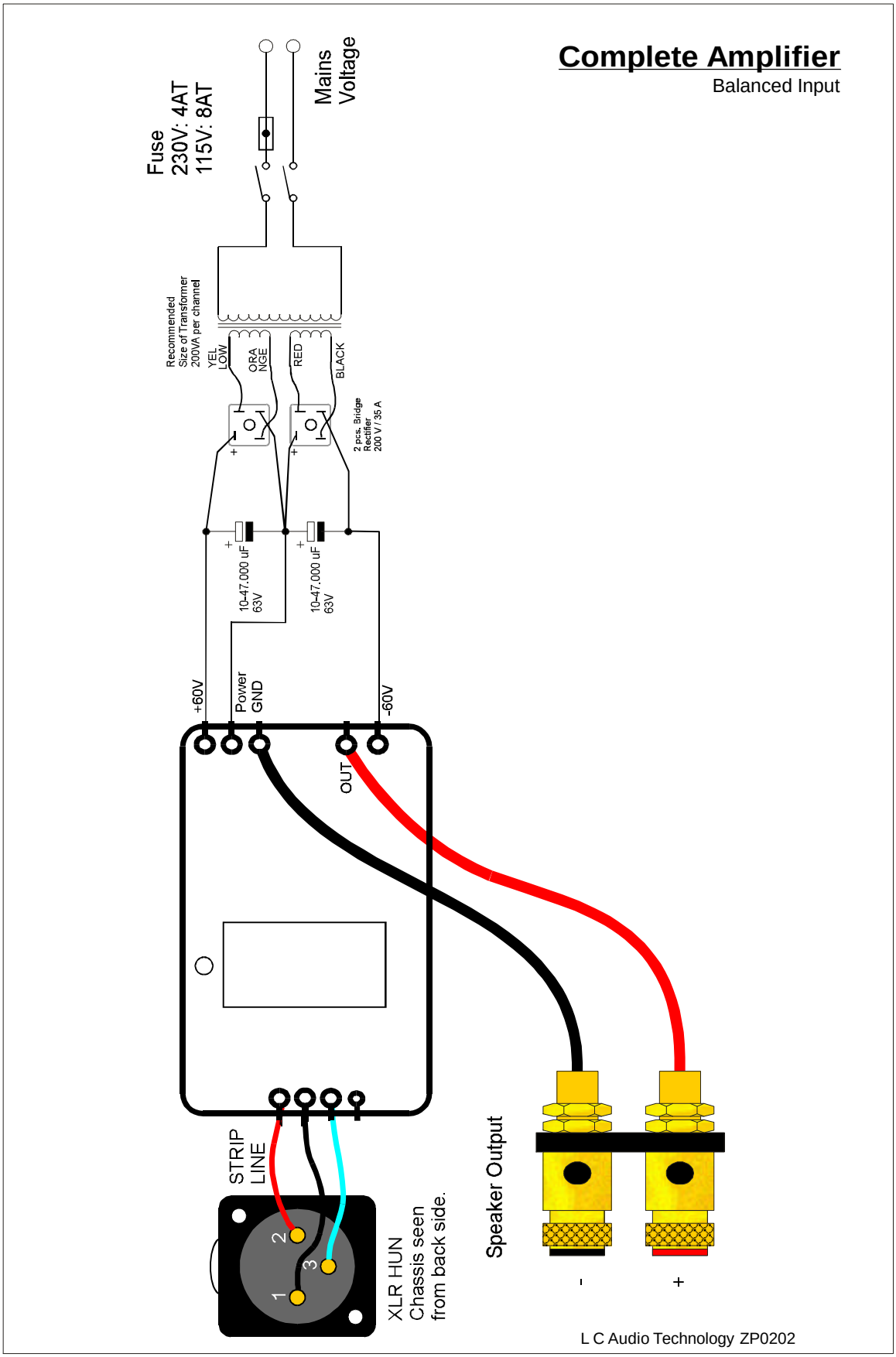
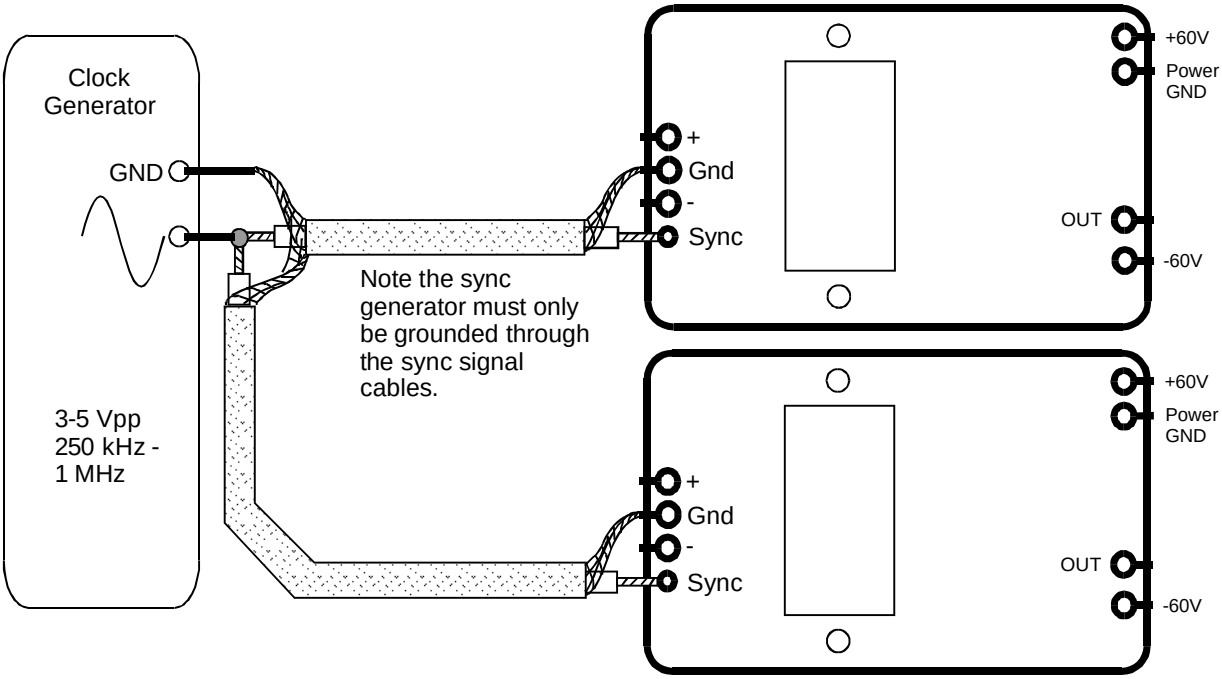
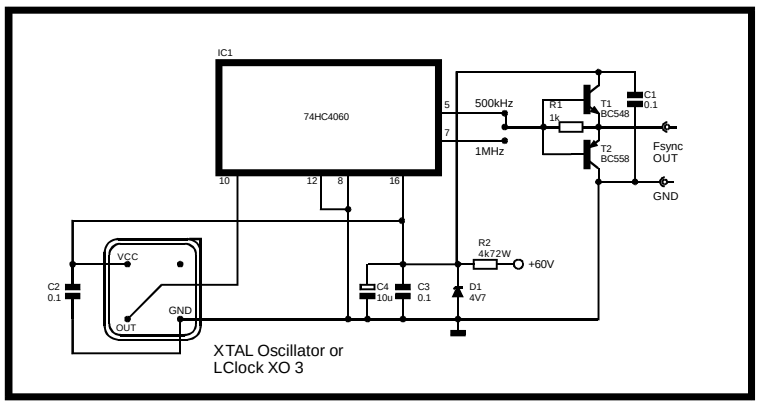


Sync Mode.

If you simply connect ZAPpulse modules to a power supply, they will run in the free running mode, at some 490 kHz. This works fine, but in some cases it is beneficial to alter or syncronize the switching frequency. Especially if you have several channels in one enclosure, the sync mode will reduce the total EMC noise, and improve sound quality. Or if you wish to have a completely syncronized Audio System, with the amplifier running syncronous with tha D/A converter and CD transport. You can control the switching frequency with an external oscillator simply by applying the clock signal to the Sync. input. Either TTL 0-5 V square wave signals or DC centered Sinus Waves will do as long as they are free from audible noise and jitter. Frequencies of 250kHz to 1 MHz will work fine.
Each module loads the sync signal with a 2.5 kOhms resistive load.





A good clock generator for ZAPpulse 2.1 can be made this way. For normal applications a can cmos oscillator is adequate, and for high end applications, we recommend an LClock XO 3. 500 kHz or 1MHz is selectable.

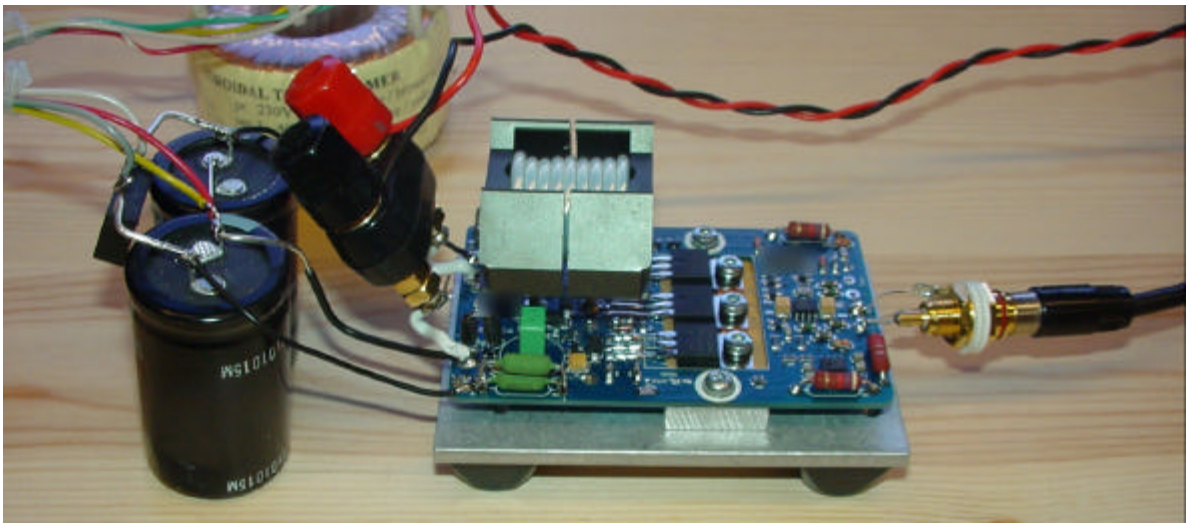
The frequency is 16,9344 MHz, so in many cases the CD transport and D/A Converter can be syncronized to the same clock.

Cooling Requirements.

Cooling requirements depends on the applied supply voltage, as most of the heat is generated in idle mode, with no load. If you want to be sure to have appropriate cooling, simply use a A5 size (½ Letter) size aluminum sheet per module. But less will do. A 200 Watt stereo amplifier can be cooled just using the bottom of a thin steel sheet 19" Rack enclosure (42 x 30 cm). Even playing at full power for extended periods will not thermally overload the ZAPpulse amplifier.
So the obvious cooling solution would most often be to place the modules on the enclosure floor or side walls.

With smaller power supplies of +/- 35 - 40 V which gives powers of 50 - 80 Watts in 8 Ohms, no heat sinking or cabinet fastening is called for at all.
Not all power is disappated in the heat sink, some 3-5 Watts are disappated in the power resistors on the board, and 1-2 Watts in the filter choke all depending on signal load.

A thermal protection circuit will shut the module down at around 100 deg. C.



Minimum System...

100 Watt RMS ZAPpulse MONO block amplifier built with only (almost) credit card size heat sinking. It will actually provide continous power of 100 Watts RMS in 8 Ohms, after ½ hour operation this amplifier was only around 40 deg. C Caps are 4700uF/63V. Despite the simple application, this mono block amplifier performs great, and has plenty of dynamics, definition and details. A set of these was used in the Copenhagen Audio Fair 2003 to demonstrate ZAPpulse qualities on the TANNOY Dimension TD12. It shows how simple a complete ZAPpulse amp. is to build.

ZAPpulse Concept

Shopping list

...All you need to build a complete ZAPpulse 2.1 High End Audio Amplifier w/ approximate prices..

2 ZAPpulse 2.1 modules	USD 430
2 Electrolytic Caps 10000uF / 63V	USD 20 - 100 (depending on quality))
2 Bridge Rectifiers 35 A 200 V	USD 8
1 Transformer 2 x 42 V AC 500 VA	USD 80
1 DC Filter (avoid mechanical humming))	USD 30
1 set RCA receptables	USD 7
1 set XLR female chassis sockets	USD 16
2 set Speaker Terminals	USD 16 - 60 (depending on quality)
1 enclosure, metal	USD 70 - 1000 (dep. on design and quality)
1 IEC Mains inlet with Fuse Holder	USD 2
1 m. TEFLAR speaker wire for internal	USD 5
1 m. Stripline signal wire for internal	USD 16

+ optionally:

1 volume potentiometer 10k stereo, LOG	USD 16
1 Knob	USD 16
1 - 3 Blue LED's w/ Resistor 10k	USD 8

Complete assemply parts price for a 2 ch. 200 Watts RMS amplifier varies from USD 800 to USD 2000 depending primarily on the enclosure.

***ZAPpulse Concept**, shown above in the standard 19" 2U Rack w/ ALPS Rk40 Volume Control sells in kit form for USD 860.*

Home Cinema Amplifier System.

ZAPpulse 2.1 is ideal to build multichannel amplifiers. The small size and lack of heat sink requirements allows for very compact applications of 5 - 7 or 8 channel amplifiers with high power. Enough power and performance to meet professional Cinema requirements.
Our V4P power Supply board is perfect for multichannel amplifiers, as it has connection for up to 8 channels. For normal use one 500 VA transformer is enough to drive 5 channels of 200 Watts RMS (total 1000 Watts Audio Power) because there is no thermal loss in the amplifiers, and even if the power at clipping level is 1000 Watts total, the average power cointent of a signal integrated over a period of ½ hour (thermal time constant of the transformer), is only less than 50%.
A complete 5 ch. 200 Watts can be built for around 1500 USD. A bigger professional Cinema amplifier with 6 ch. 200 Watts plus 1 ch. 800 Watts sub. and 1.5 kW transformers can be built for around 2500 USD.

Active Crossover.
Another obvious application for ZAPpulse 2.1 is a system amplifier where the crossover is made with small signal parts, before the amplifier stage. The advantages of this are many. First the cross over parts cost close to nothing, so it is cheap to experiment. The damping factor is optimal in the entire freq. range, whereas in passive x-overs, the damping factor is very poor in the cross regions. Very high sound pressure levels can be achieved, with this method, as you can not hear if the bass amp. is clipping as long as the mid. amp. is not. This is always used in Rock Concerts as it is much more efficient than bridging amplifiers to huge output powers. In this way there is no need for passive x-over networks in the speakers, the ZAPpulse amps are connected DIRECTLY to the speaker driver. (In these new versions there is no pop noise at power up / down).

The filter board with 1 - 2 - 3 or 4th order high and low pass filters plus level control for each output and powersupply can be purchased from us at only the price of one good filter coil. (USD 160).

See www.lcaudio.dk/filters.htm

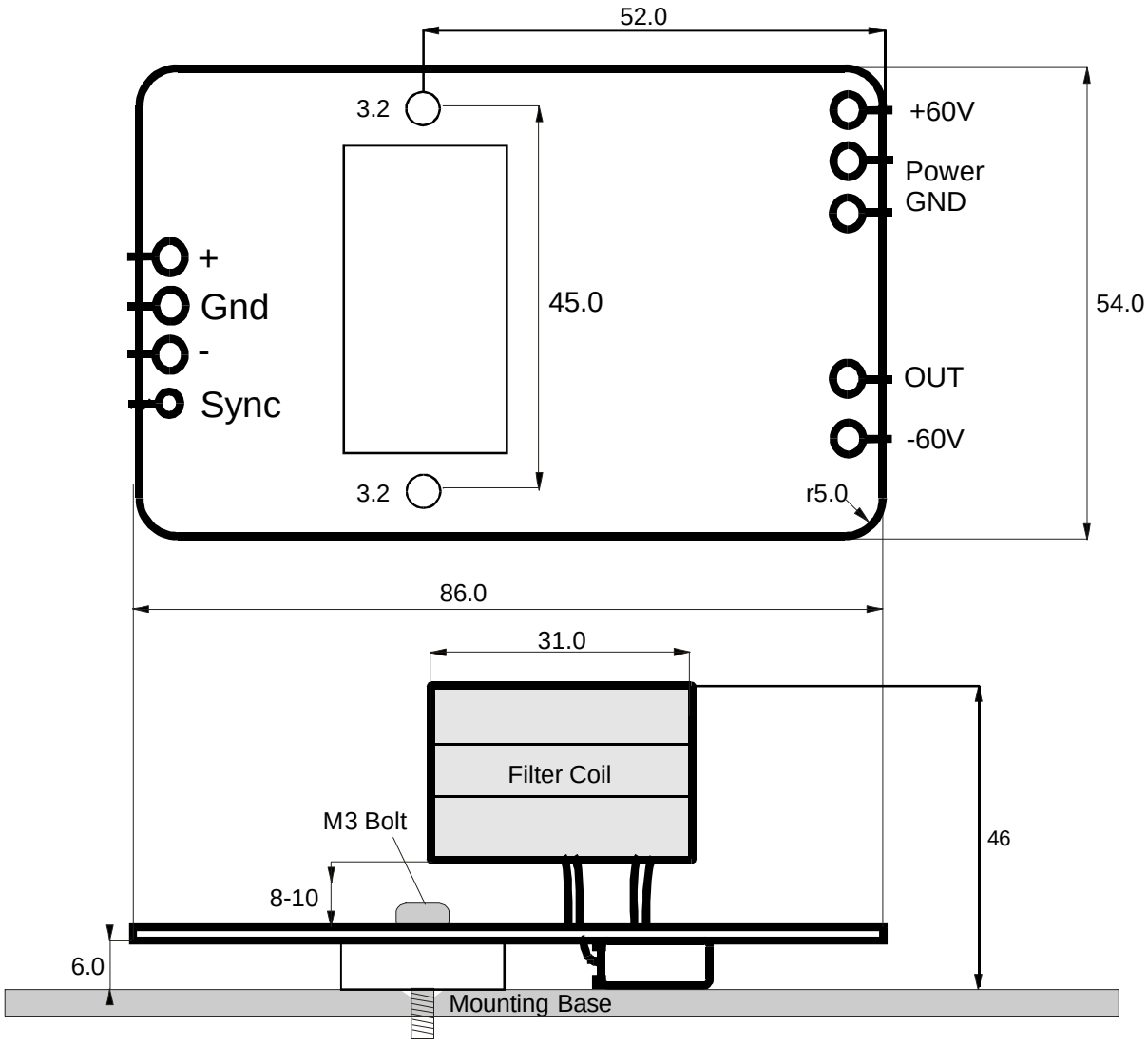
A First order simple filter can even be made with only the ZAPpulse module and one capacitor. HP or LP.

Professional Use
Despite the small size of these modules, they are extremely rugged. They can produce vast amounts of distortion free and clean Audio Power. The lack of heat disappation means that it is hard to overload a ZAPpulse module.

Balanced input and short circuit protection are standard professional features on every ZAPpulse module. To allow for trouble free field operation we recommend building in DC blocking and HF filtering on the input.
Simply connect a 3.9 uF and 301 Ohms in series with each signal input, and 10n from each signal to gnd (after the 301 Ohms).

A ZAPpulse 2.1 will sound much better than any normal PA Amplifier, and no cooler fans, heavy power supplies or huge heat sinks are needed at all!

Mechanical data and mounting information.



L C Audio Technology ZP0202

NOTES on mounting of ZP 2.1 Modules..

The mounting surface should preferably be of heat conducting metal such as Aluminium, Copper, Brass or other semi or high conducting metals.

Surface must be smooth, and free drilling particles, oil, liquids and dirt.

When mounting on rough or painted surface, use a standard heat conducting paste.

The M3 hole in the mounting base must be cleared with a 0.5 mm. recession to avoid metal splinters from tilting the modules.

The aluminum block on ZP0202 is electrically isolated, and conducts no voltage.

Fasten mounting screws tightly, and assure they have a tight grip in the mounting Base.

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