

DLS ZM1, Z-match

General

DLS Z-match is an impedance-matching transformer for speaker loads.

It can be used for transforming up or down the output voltage from a car amplifier to the speaker/speakers.

You may have had the problem that you want to connect two 4 ohm subwoofers in bridge mode to an amplifier. Since most amplifiers are 2 ohm stable this is impossible without destroying the amplifier. But with a Z-match you can solve this problem easily.

Transforming up

If a voltage is transformed up the amplifier normally produces more power. This relation is useful if the speaker/speakers has a high impedance, and the amplifier tolerates low impedances.

With a DLS Z-match the voltage can be transformed up with +41%, +100% or +182%.

It can be described that the amplifier senses a lowered speaker impedance to half, to 1/4 or to 1/8.

Transforming down

If the voltage is transformed down the amplifiers output impedance better matches a low-ohm load, for example several speakers connected in parallel.

Here the transformer is used backwards and can transform the voltage down to 70%, 50% or 35% of the full voltage. The amplifier senses an increase of the speaker impedance to 2 times, 4 times or 8 times.

By using different combinations the impedance can be changed in more than 25 different steps.

Besides the use as an impedance-matching transformer the DLS Z-match evens the impedance peak that occurs at the resonant frequency and in that way the impedance load is improved for the amplifier.

CAUTION!

If an amplifier is loaded with a lower impedance than it is designed for it can be damaged, especially if the load lasts for a longer period.

DLS takes no responsibility for damaged amplifiers or speakers if they have been connected to a DLS Z-match.

DLS Z-match is mainly designed for increasing the amplifier output by loading it with a low impedance load. (not lower than the lowest load recommended by the producer). Be aware that when the amplifier output increases the damping factor gets lower. The damping factor is the amplifiers ability to control the speaker cone movement as precise as possible. This means that an amplifier with a low damping factor will be worse when the amplifier is loaded down and the output gets higher. The higher output power is achieved on the cost of lower damping factor.

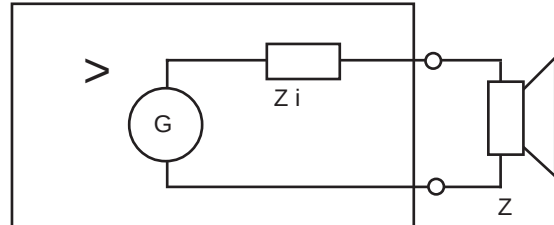
On the other hand, when transforming up the speaker impedances the damping factor will be increased accordingly.

Maximum power handling capacity for the DLS Z-match is 500 Watts.

1. Output impedance of the amplifier

A modern car amplifier is always designed in such a way that it tries to give a constant voltage output independent of the speaker load impedance.

Let us study this drawing:



In this example the amplifier has an output power of 50 Watts in a 4 ohm load. V

Load	Output (V)	Power (U^2 / Z)
8 ohm	16 Volt	$16 \times 16 / 8 = 32$ Watt
4 ohm	14 Volt	$14 \times 14 / 4 = 49$ Watt
2 ohm	12 Volt	$12 \times 12 / 2 = 72$ Watt
1 ohm	8 Volt	$8 \times 8 / 1 = 64$ Watt

This amplifier is recommended by the producer not to be loaded below 2 ohms, it is what we normally say, 2 ohm stable. It can be loaded with a speaker impedance of 2 ohms in stereo mode without being damaged. If it gets too hot there are hopefully some protection circuits that shuts the amplifier down until it has cooled off. Amplifiers that are used at high volumes for long periods might need to have an extra cooling with one or more fans.

We can see that the output power increases when the speaker load decreases, down to two ohms. At 1 ohm load the output power gets less again, so it's no meaning to load the amplifier that low. The amplifier will probably be damaged after some time, and the distortion will also increase.

All amplifiers has an internal impedance, see the drawing above where it is called Z_i . As the amplifier is loaded with lower and lower speaker impedances the loss of heat increases in Z_i . Maximum output is obtained when the speaker impedance load is equal to the internal impedance of the amplifier. In the example above the internal impedance seems to be around two ohms.

It is not obvious that all amplifiers can be loaded down to its internal impedance. Many amplifiers have protection circuits that shuts the amplifier off, and some amplifiers will broke at low impedance loads.

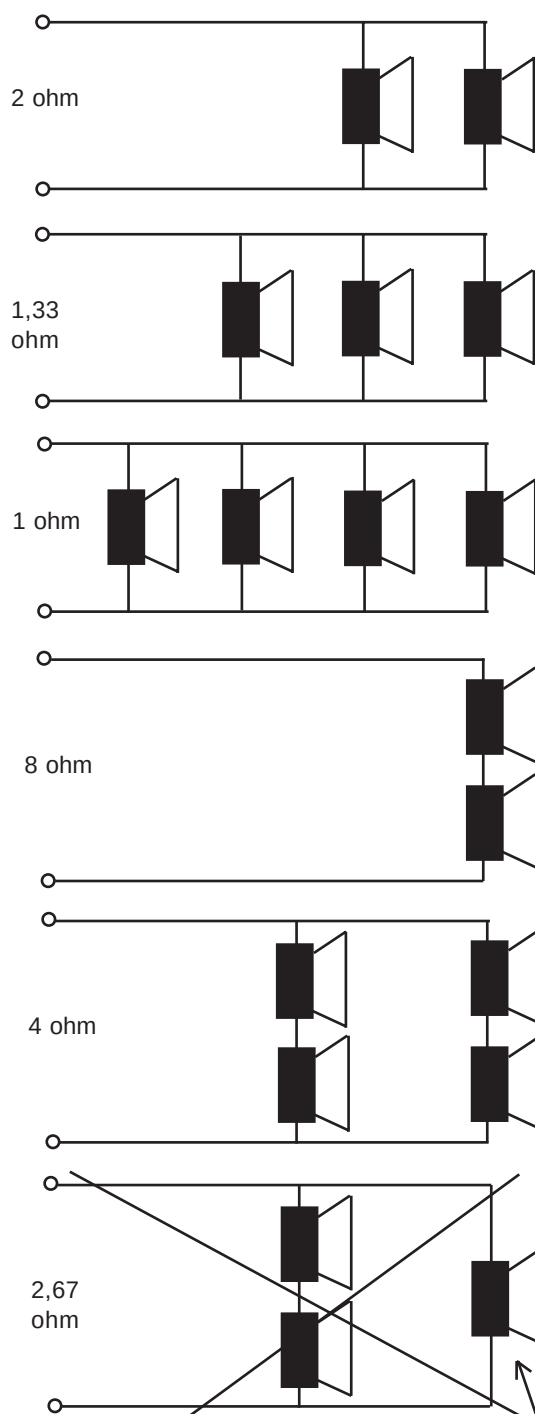
Conclusion: An amplifier can not be loaded below the limit set by the producer. High ambient temperatures, long-time playing at high volumes and speakers with a "mean" impedance curve demands a good external cooling and here the DLS Z-match can be used only to improve the impedance matching between amplifier and speakers.

2. Speaker impedances:

Most speakers for car use has an impedance of 4 ohms. The speakers can be connected in many different ways to obtain the wanted impedance. They can be connected in series, in parallel or other combinations.

Speakers with dual voice coils are normally connected as if they were two speakers.

The examples below shows different ways to connect speakers and the resulting impedance obtained when using 4 ohm speaker elements.



This example should never be used. The speaker to the right plays with four times more power than the two others.

When two speakers are connected in parallel the impedance is halved.

When two speakers are connected in series the impedance is doubled.

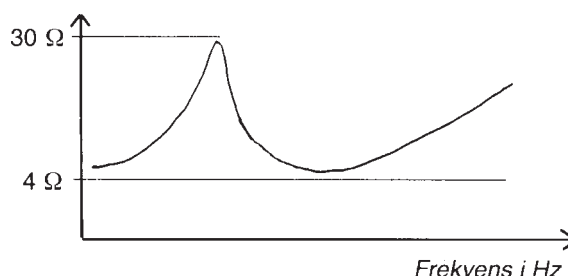
This is for identical speakers having the same impedance.

In the examples we see the speakers as resistors, a component used for electronic devices which has a resistance not varying with the frequency.

The resistance of a speaker can be measured with an omh-meter. The so called DC resistance is normally 80 % of the speaker impedance. A four ohm speaker has a DC resistance of approximately 3,2 ohms.

The impedance is the resistance for alternating current (AC).

All speakers has an impedance that varies with the frequency with a peak at the resonant frequency (Fs). The nominal impedance is the lowest impedance the speaker has in the impedance curve, see the drawing below.



At the resonant frequency the speaker has an impedance of 15 - 30 ohms when the nominal impedance is 4 ohms. The impedance curve is also influenced if it's placed inside an enclosure, and also how this enclosure is designed.

Some types of vented boxes makes the impedance curve more "mean" as seen from the amplifier.

Some subwoofers has an impedance lower than the nominal 4 ohms and can be very "mean" to the amplifier. It is not quite sure that an amplifier loaded with 4 ohms are happy with that if it handles 4 ohm load with only small tolerances. The amplifier in our example should be able to handle also "mean" 4 ohm speakers.

Two "mean" 4 ohm speakers in parallel offers a resulting two ohm load, but still a "mean" two ohm load.

The amplifier in our example should probably don't like a "mean" two ohm load.

With the DLS Z-match you can improve the impedance curve and the amplifier will sense a nicer load.

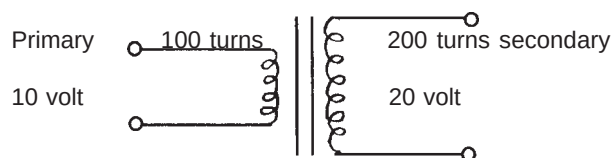
In the example above a "mean" two ohm load can be transformed into a nicer four ohm load to the price of a little lower output, but improved sound.

But the normal use of the Z-match is to increase the power output from the amplifier by loading it down.

3. DLS Z-match:

DLS Z-match can be described as a transformer with many taps (terminals).

An ordinary transformer has a primary side and a secondary side.



The transformer above has a primary side of 100 turns of heavy copper wire on an iron core, and a secondary side of 200 turns of not so heavy copper wire on the same core.

This transformer transforms a primary voltage of for example 10 volts to a secondary voltage of 20 volts.

If you connect 10 volts to the secondary side you will have 5 volts out on the primary side.

If the transformer is designed to be used for audio frequencies, and for impedances of one up to 10 ohms it can be used to transform the impedance of a speaker to become higher or lower.

If a 4 ohm speaker is connected to the primary side, the one with 100 turns, an amplifier connected to the secondary side will sense a speaker impedance of 16 ohms.

This calculated with this formula: $Z_s = Z_p \times (n_2 / n_1)^2$

Z_p is the impedance of the speaker connected to the primary side, in this case 4 ohms. n_2 / n_1 is the ratio between the number of turns on the secondary side (n_2) and the number of turns on the primary side (n_1)

In this case the ratio is 200 turns / 100 turns = 2.

This is also the ratio between the secondary voltage and the primary voltage, 20 volts / 10 volts = 2.

Put the figures into the formula and the result is

$Z_s = 4 \times 2 \times 2 = 16$.

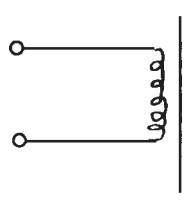
If we connect our speaker to the secondary side instead, and calculate the impedance the amplifier sees when it's connected to the primary side.

Here the speaker impedance will be divided by four and the amplifier sees a 1 ohm load. With this simple transformer I can increase a speaker impedance by four times, or divide it by four.

If you add two taps to the secondary winding, one at 100 turns, one at 141 turns and add some more turns it can be as below:

Primary side:

Tap 1 100 turns
for ex. 10 Volt



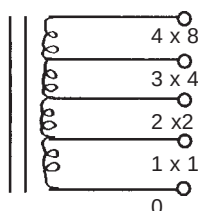
Secondary side:

Tap 4 283 turns
gives 28 Volts

Tap 3 200 turns
gives 20 Volts

Tap 2 141 turns
gives 14 Volts

Tap 1 100 turns
gives 10 Volts



If you repeat the calculations you will find that:

A four ohm speaker connected to the primary side, and an amplifier connected to the secondary side senses:

On tap 1: 4 ohms

On tap 2: 8 ohms, the impedance x 2

On tap 3: 16 ohms, the impedance x 4

On tap 4: 32 ohms, the impedance x 8

If you connect the speaker to the secondary side, and an amplifier to the primary side it will sense: (when the speaker is connected to the following taps)

0 and tap 1: 4 ohms, divided by 1

0 and tap 2: 2 ohms, divided by 2

0 and tap 3: 1 ohm, divided by 4

0 and tap 4: 0,5 ohm, divided by 8

This is the principles behind the Z-match. But it differs on some points.

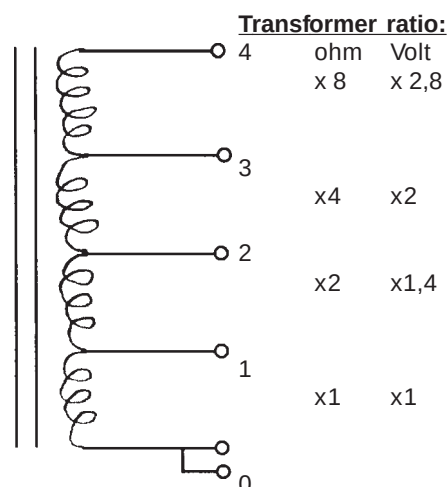
The transformer described above is a transformer with separate primary and secondary windings insulated from each other.

DLS Z-match is an auto-connected transformer with a single winding equivalent to the secondary winding above.

In this way the power handling capacity is increased and it makes the transformer cheaper and not so heavy.

The transformer losses will increase at frequencies over 10 kHz, especially when you use the x 8 terminal. This is normally no problem since the Z-match is mostly used for subwoofers.

When connecting speakers to a car amplifier it is very important that no connections comes near and in contact with the vehicle - ground. The same is for all connections to the Z-match.



3. Amplifiers in bridge mode

In chapter one we described the output impedance on an amplifier. We presumed that the amplifier had two channels and studied how it could be loaded down in stereo mode, that is with speakers connected in stereo to each channel.

Most car stereo amplifiers can also be used as mono amplifiers. We call this mono bridge mode operation. The amplifiers can be run in multimode operation or tri-mode.

All bass sound below 100 Hz are normally recorded in mono. There is no need to have a subwoofer for each channel. It is better to use the amplifier in mono connected to a bass enclosure containing one or more subwoofers.

Most car amplifiers are stereo. They have two channels connected two separate speakers, normally a front or rear system. For bass reproduction we can use an identical or maybe a more powerful amplifier. Sometimes a four channel amplifier is to be preferred.

In bridge mode both amplifier channels are connected in a way so that a mono subwoofer can be connected between L+ and R- (see the amplifier manual for correct information).

Actually both amplifiers are internally connected in series causing the output voltage to double. At an unchanged load (4 ohm) the power output is increased 4 times compared with if the speaker was connected to only one channel. The double voltage has caused a twice as high current. The power $P = U \times I$, the new power is $P = 2U \times 2I = 4 \times U \times I$.

It means that an amplifier with 2 x 50 Watt output in stereo can deliver up to 200 Watts to a 4 ohm speaker connected in bridge mode.

It is very important to understand that each channel of the stereo amplifier see half the actual speaker impedance.

If you load an amplifier in bridge mode with 4 ohms each amplifier part senses a 2 ohm load. If the amplifier can't handle 2 ohm loads (not 2 ohm stable) the amplifier's protection circuits will shut off the amplifier, or it will be damaged.

If two 4 ohm subwoofers are connected in parallel, resulting in a 2 ohm speaker impedance, the amplifier senses a 1 ohm load per channel. If this load also is "mean" the amplifier shuts off or burns.

In this situation you must use a DLS Z-match to increase the impedance sensed by the amplifier.

Here you simply connect the 2 ohm load to terminal 0 and 2, and the amplifier is connected to terminal 0 and 3.

The speakers can also be connected in series to 8 ohm and connected to terminal 0 and 4. The amplifier is connected to terminal 0 and 3 as before.

Examples:

- My amplifier can handle 2 ohm loads in bridge mode.
- My two subs has 4 ohm impedance each.

If I connect a 4 ohm sub per channel I will have 100 Watts per channel.

With a two ohm load per channel I will have 180 Watts per channel.

This means a four ohm load in bridge mode.

I can choose between:

1. Connecting the subs in parallel to two ohms..
Connect the subs between terminal 0 and 2.
Connect the amplifier between terminal 0 and 4
Now you get $2 \times 180 \text{ Watts} = 360 \text{ Watt mono}$ out from the amplifier. [\[see page 6, example 3\]](#)
2. Connecting the subs in series to eight ohms.
Connect the subs between terminal 0 and 4.
Connect the amplifier between terminal 0 and 3.
Now you get $2 \times 180 \text{ Watts} = 360 \text{ Watt mono}$ out from the amplifier. [\[see page 6, example 5\]](#)

Check carefully that nor the amplifier nor the Z-match gets too warm. If the sound quality becomes bad, choose another load (higher).

Another example:

With the same amplifier as above I want to use a bass box enclosure with three 4 ohm subs.

You can connect all three in parallel resulting in 1,33 ohm impedance.

Or in series to $4 \times 3 = 12 \text{ ohm}$.

In the first case we need to multiply the load with a factor 3, or at least 2,40.

There are the following alternatives:

2,40, that is $2,40 \times 1,33 = 3,2 \text{ ohm}$

2,85, that is $2,85 \times 1,33 = 3,8 \text{ ohm}$

3,35, that is $3,35 \times 1,33 = 4,45 \text{ ohm}$

[\[see page 6, example 2\]](#)

When connecting the speakers in series I need to multiply the load with x 0,33 giving the following alternatives:

x 0,25 , that is $0,25 \times 12 = 3,0 \text{ ohm}$

x 0,30 , that is $0,30 \times 12 = 3,60 \text{ ohm}$

x 0,35 , that is $0,35 \times 12 = 4,20 \text{ ohm}$

x 0,42 , that is $0,42 \times 12 = 5,04 \text{ ohm}$

[\[see page 6, example 6\]](#)

As you can see there are solutions to most adaption problems. On the following pages there are examples on the most common ways to connect subwoofers to amplifiers.

Turbo-button

Among competitors in dB dragracing (SPL contests) it is popular to increase the power by loading down the amplifier for just a few seconds during the measure.

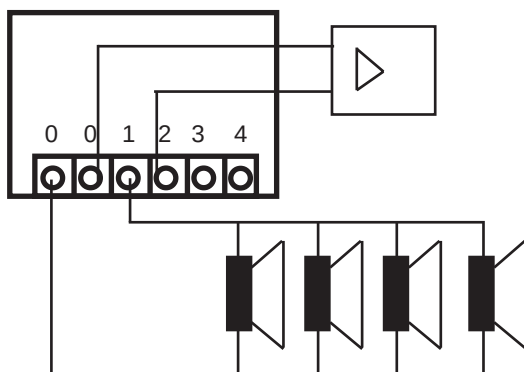
If you want to do this you must find the limit for what the amplifier and speaker can handle during this short period of time.

On the following pages we present the most common ways of connecting the Z-match. If you are familiar with the technique of transforming we are sure that you can find more ways of connecting the Z-match.

Connections with amplifiers that can handle 2 ohm load in bridge mode, or 1 ohm in stereo mode. (1-ohm stable)

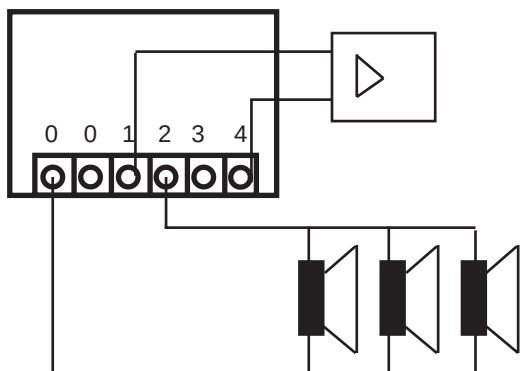
In all examples below 4 ohm speakers are used.

1. With 1 ohm speaker load:



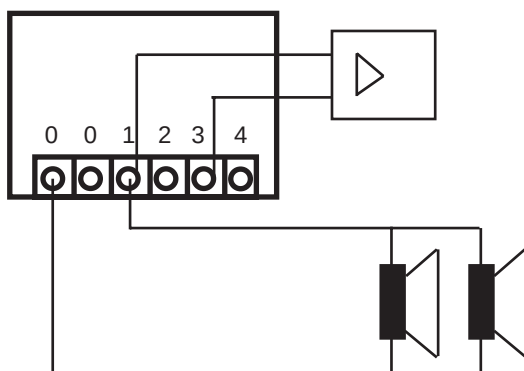
Amplifier connected between 0 - 2, sees a 2 ohm load
Speakers connected between 0 - 1, (1 ohm load)

2. With 1,33 ohm speaker load:



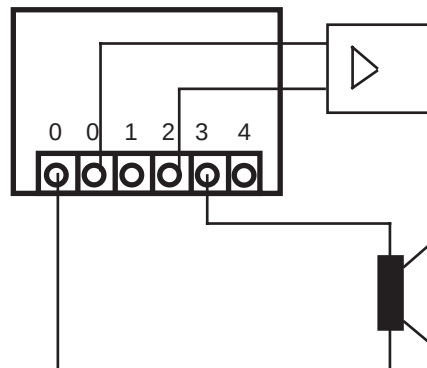
Amplifier connected between 1 - 4, sees a 2.2 ohm load
Speakers connected between 0 - 2, (1,33 ohm load)

3. With 2 ohm speaker load:



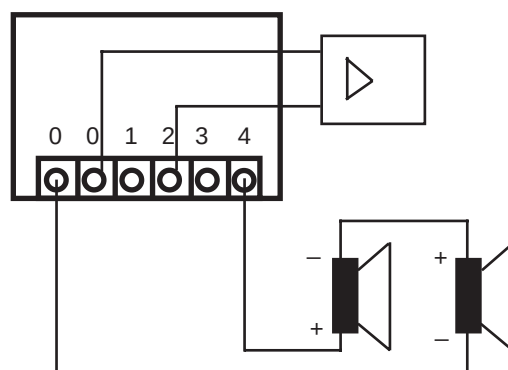
Amplifier connected between 1 - 3, sees a 2 ohm load
Speakers connected between 0 - 1, (2 ohm load)
Used only as an impedance corrector. The amplifier load becomes "nicer".

4. With 4 ohm speaker load



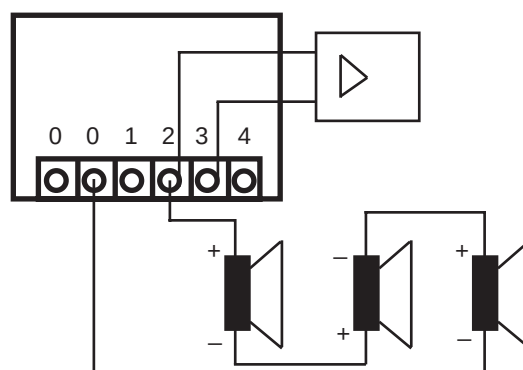
Amplifier connected between 0 - 2, sees a 2 ohm load
Speakers connected between 0 - 3, (4 ohm load)

5. With 8 ohm speaker load



Amplifier connected between 0 - 2, sees a 2 ohm load
Speakers connected between 0 - 4, (8 ohm load)

6. With 12 ohm speaker load



Amplifier connected between 2 - 3, sees a 2 ohm load
Speakers connected between 0 - 2, (12 ohm load)

Summary:
Connections with amplifiers that can handle 1 ohm load in bridge mode, or 2 ohm in stereo mode.

Speaker load	Connect amplifier to terminal:	Connect speakers to terminal:	Amplifier see the load as:
1 ohm	0 - 2	0 - 1	2 ohm
1,33 ohm	1 - 4	0 - 2	2,22 ohm
2 ohm	1 - 3	0 - 1	2 ohm
4 ohm	0 - 2	0 - 3	2 ohm
8 ohm	0 - 2	0 - 4	2 ohm
12 ohm	2 - 3	0 - 2	2 ohm

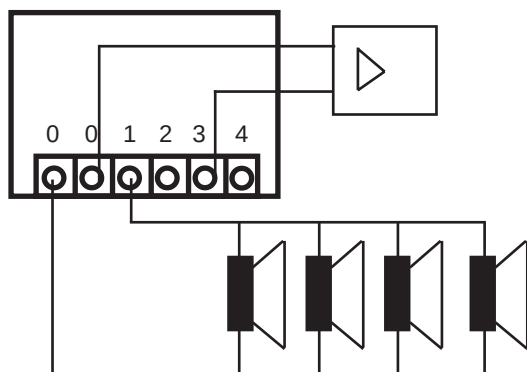
Connections with amplifiers that can handle 4 ohm load in bridge mode, or 2 ohm in stereo mode.

(2-ohm stable)

This type of amplifiers is the most common. They are what we say "2 ohm stable". They can be loaded with 2 ohm in stereo and 4 ohm in mono bridge mode.

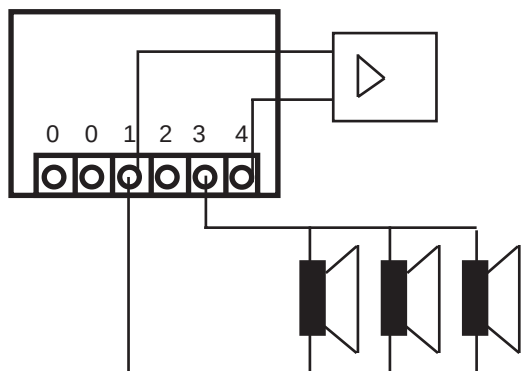
In all examples below 4 ohm speakers are used.

1. With 1 ohm speaker load:



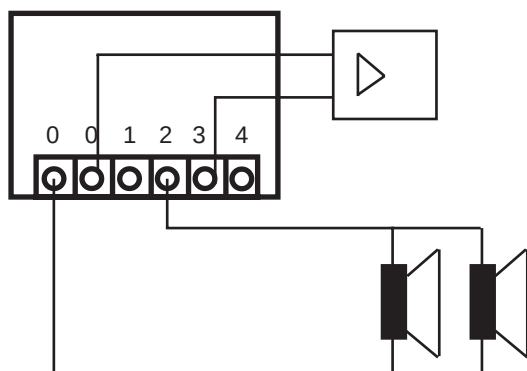
Amplifier connected between 0 - 3, sees a 4 ohm load
Speakers connected between 0 - 1, (1 ohm load)

2. With 1,33 ohm speaker load



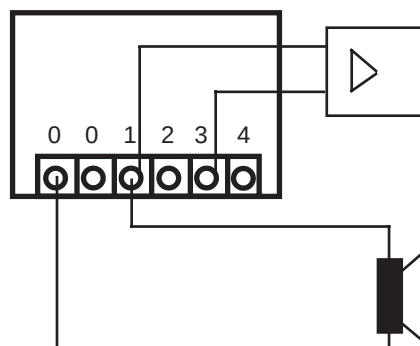
Amplifier connected between 1 - 4, sees a 4,45 ohm load
Speakers connected between 1 - 3, (1,33 ohm load)

3. With 2 ohm speaker load



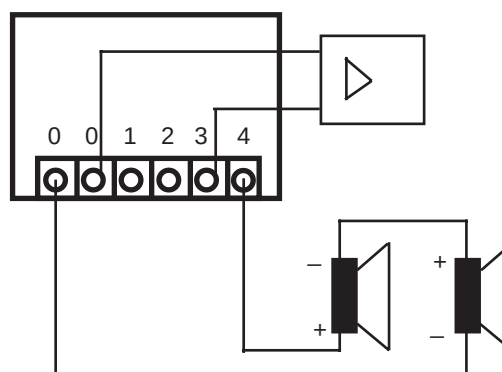
Amplifier connected between 0 - 3, sees a 4 ohm load
Speakers connected between 0 - 2, (2 ohm load)

4. With 4 ohm speaker load



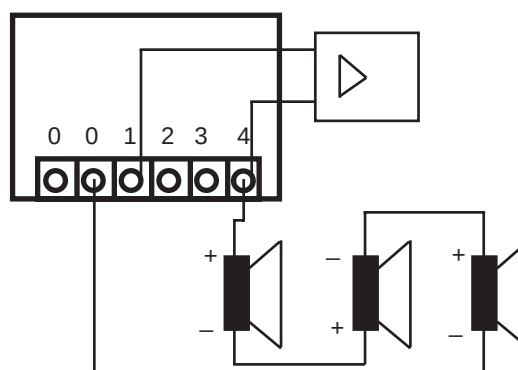
Amplifier connected between 1 - 3, sees a 4 ohm load
Speakers connected between 0 - 1, (4 ohm load)
Used only as an impedance corrector. The amplifier load becomes "nicer".

5. With 8 ohm speaker load



Amplifier connected between 0 - 3, sees a 4 ohm load
Speakers connected between 0 - 4, (8 ohm load)

6. With 12 ohm speaker load



Amplifier connected between 1 - 4, sees a 5 ohm load
Speakers connected between 0 - 4, (12 ohm load)

Summary:

Connections with amplifiers that can handle 4 ohm load in bridge mode, or 2 ohm in stereo mode.

Speaker load	Connect amplifier to terminal:	Connect speakers to terminal:	Amplifier see the load as:
1 ohm	0 - 3	0 - 1	4 ohm
1,33 ohm	1 - 4	1 - 3	4,46 ohm
2 ohm	0 - 3	0 - 2	4 ohm
4 ohm	1 - 3	0 - 1	4 ohm
8 ohm	0 - 3	0 - 4	4 ohm
12 ohm	1 - 4	0 - 4	5 ohm

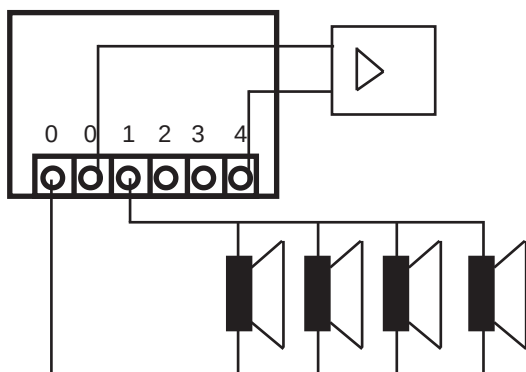
Connections with amplifiers that can handle 8 ohm load in bridge mode, or 4 ohm in stereo mode.

(4-ohm stable)

This group of amplifiers are no longer common. Only cheap or older amps can only handle a minimum of 4 ohm load in stereo mode.

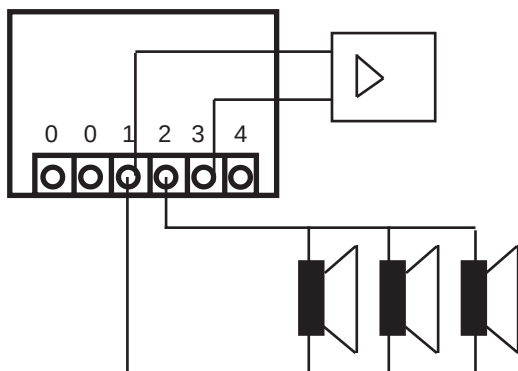
In all examples below 4 ohm speakers are used.

1. With 1 ohm speaker load:



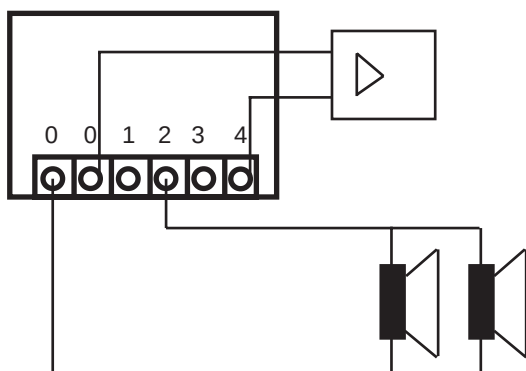
Amplifier connected between 0 - 4, sees an 8 ohm load
Speakers connected between 0 - 1, (1 ohm load)

2. With 1,33 ohm speaker load



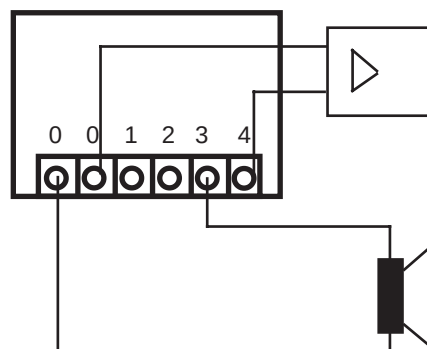
Amplifier connected between 1 - 3, sees a 7,85 ohm load
Speakers connected between 1 - 2, (1,33 ohm load)

3. With 2 ohm speaker load



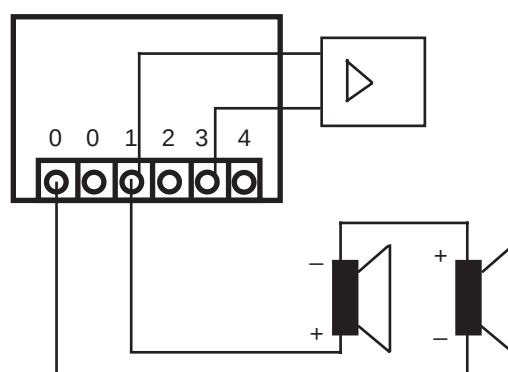
Amplifier connected between 0 - 4, sees an 8 ohm load
Speakers connected between 0 - 2, (2 ohm load)

4. With 4 ohm speaker load



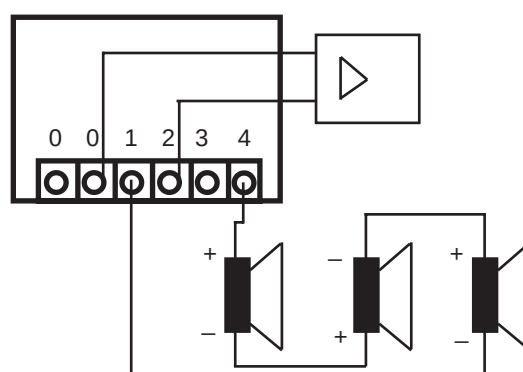
Amplifier connected between 0 - 4, sees an 8 ohm load
Speaker connected between 0 - 3, (4 ohm load)

5. With 8 ohm speaker load



Amplifier connected between 1 - 3, sees an 8 ohm load
Speakers connected between 0 - 1, (8 ohm load)
Used only as an impedance corrector. The amplifier load becomes "nicer".

6. With 12 ohm speaker load



Amplifier connected between 0 - 2, sees a 7,2 ohm load
Speakers connected between 1 - 4, (12 ohm load)

Summary:

Connections with amplifiers that can handle 8 ohm load in bridge mode, or 4 ohm in stereo mode.

Speaker load	Connect amplifier to terminal:	Connect speakers to terminal:	Amplifier see the load as:
1 ohm	0 - 4	0 - 1	8 ohm
1,33 ohm	1 - 3	1 - 2	8 ohm
2 ohm	0 - 4	0 - 2	8 ohm
4 ohm	0 - 4	0 - 3	8 ohm
8 ohm	1 - 3	0 - 1	8 ohm
12 ohm	0 - 2	1 - 4	7 ohm

Other alternatives for connecting Z-match.

This is a table with more alternatives of impedance ratios than the ones on previous pages.
Suitable for you who looks for alternative connections.

Impedance ratio x	Speaker load (ohm)	Amplifier see a load of: (ohm)	Connect amplifier to terminal:	Connect speaker load to terminal:
0,125	8 16	1 2	0 - 1 0 - 1	0 - 4 0 - 4
0,17	8 12 16	1,35 2 2,7	1 - 2 1 - 2 1 - 2	1 - 3 1 - 3 1 - 3
0,18	8	1,4	2 - 3	0 - 2
0,20	8	1,6	3 - 4	1 - 4
0,25	4 8	1 2	0 - 1 0 - 2	0 - 3 0 - 4
0,30	8	2,4	0 - 1	1 - 4
0,35	4 8	1,4 2,8	2 - 3 2 - 3	1 - 3 1 - 3
0,42	4 8 12	1,68 3,36 5,04	1 - 4 1 - 4 1 - 4	0 - 4 0 - 4 0 - 4
0,48	4 8	1,92 3,84	1 - 2 1 - 2	2 - 3 2 - 3
0,50	4 8	2 4	0 - 2 0 - 3	0 - 3 0 - 4
0,60	4 8 12	2,4 4,8 7,2	0 - 2 0 - 2 0 - 2	1 - 4 1 - 4 1 - 4
0,69	4	2,75	3 - 4	0 - 1
0,85	4	3,33	1 - 4	0 - 3
1	4	4	1 - 3	0 - 1
1,20	2 4	2,4 4,80	0 - 3 0 - 3	1 - 4 1 - 4
1,45	1,33 2	1,93 2,90	1 - 3 1 - 3	3 - 4 3 - 4
1,67	1,33 2	2,22 3,33	1 - 4 1 - 4	0 - 2 0 - 2
2	1 2 4	2 4 8	0 - 2 0 - 3 0 - 4	0 - 1 0 - 2 0 - 3
2,4	1 2	2,40 4,80	0 - 4 0 - 4	1 - 4 1 - 4
2,85	1	2,85	0 - 1	2 - 3
3,35	0,5 1 1,33	1,65 3,35 4,46	1 - 4 1 - 4 1 - 4	0 - 1 0 - 1 0 - 1
4	0,5 1	2 4	0 - 3 0 - 3	0 - 1 0 - 1
4,85	0,5 1	2,53 4,85	1 - 4 1 - 4	3 - 4 3 - 4
5,9*	0,5 1 1,33	2,95 5,90 7,85	0 - 1 0 - 1 0 - 1	1 - 2 1 - 2 1 - 2
8	0,5 1	4 8	0 - 4 0 - 4	0 - 1 0 - 1
11,.*	0,5 1	6 12	0 - 2 0 - 2	1 - 2 1 - 2



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* test carefully, only recommended for short period testing