White Paper No. 6
More voltage and more current

1 Multi-amplifier systems

With the amplifiers of the A1110-X-X product range it is possible to build up multi-amplifier systems for higher output voltages and output currents. This power increase is achieved by parallel and/or serial operation of several adequate amplifier models.

Models	parallel	serial	U_{out_max}	$I_{out-max}$	Slew rate	$I_{out-pulse*}$
A1110-5-X	2		75 V_{peak}	22 A_{peak}	100 V/µs	
A1110-5-X	3		75 V_{peak}	30 A_{peak}	100 V/µs	
A1110-5-X	4		75 V_{peak}	40 A_{peak}	100 V/µs	
A1110-5-X		2[1]	150 V_{peak}	10 A_{peak}	175 V/µs	
A1110-5-X		2	150 V_{peak}	10 A_{peak}	175 V/µs	
A1110-5-X		3	225 V_{peak}	10 A_{peak}	250 V/µs	
A1110-5-X	2	2	150 V_{peak}	22 A_{peak}	175 V/µs	
A1110-16-X	2		75 V_{peak}	56 A_{peak}	100 V/µs	105 A_{peak}
A1110-16-X	3		75 V_{peak}	81 A_{peak}	100 V/µs	160 A_{peak}
A1110-16-X	4		75 V_{peak}	105 A_{peak}	100 V/µs	200 A_{peak}
A1110-16-X		2[1]	150 V_{peak}	26 A_{peak}	175 V/µs	55 A_{peak}
A1110-16-X		2	150 V_{peak}	26 A_{peak}	175 V/µs	55 A_{peak}
A1110-16-X		3	225 V_{peak}	26 A_{peak}	250 V/µs	55 A_{peak}
A1110-16-X	2	2	150 V_{peak}	26 A_{peak}	175 V/µs	55 A_{peak}

Table 1: Combinations of A1110-X-X Amplifiers
(2[1]: differential configuration; pulse=500 ms/DT=5%, only at 16-E and 16-QE models)

Table 1 lists the possible combinations and the achievable output voltages and currents for every combination, respectively. We are happy to verify other combinations upon request.

For safe operation please comply with the notes below:

- only use equal amplifier models
- heed wiring notes and cable specifications for stable signal processing
- ensure sufficient mains supply
- contact protection for power outputs; life-threatening voltages may occur

The following sections explain the structural principles and the required adjustments for amplifier systems operated in “voltage amplifier” mode. In general, multi-amplifier systems can also be operated in “current amplifier” mode. However, this requires individual configuration of every amplifier in accordance with the concrete application and therefore is not part of the considerations below.
Please contact us in case of requirement. We will be happy to help you with implementing a multi-amplifier system for your specific requirements.

2 Current increase: Parallel operation

Through parallel connection of two identical voltage sources, such as the batteries in Figure 1, the available current is doubled. The maximum obtainable output voltage corresponds to the value of each individual voltage source.

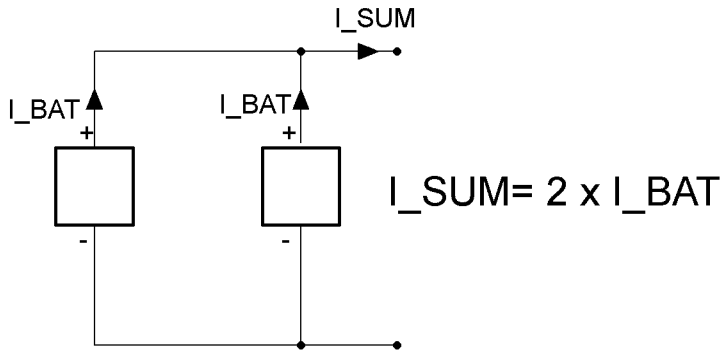

Figure 1: Two Batteries in Parallel Operation

According to this principle, the A1110-X-X amplifiers can be connected in parallel to increase the output current.
The steps required for this variant are explained below using the example of a 2-amplifier parallel system.
Since two amplifiers naturally are not exactly equal, the output voltages are not equal, either. The source with the higher voltage supplies more current than the source with the lower voltage. This asymmetry is attenuated by ballast resistances in the power outputs, which ensures “fair” current distribution: Moreover, the amplifier parameters DC offset and gain must be checked for compliance and adjusted if required (calibration instructions for the respective amplifier model are available upon request).

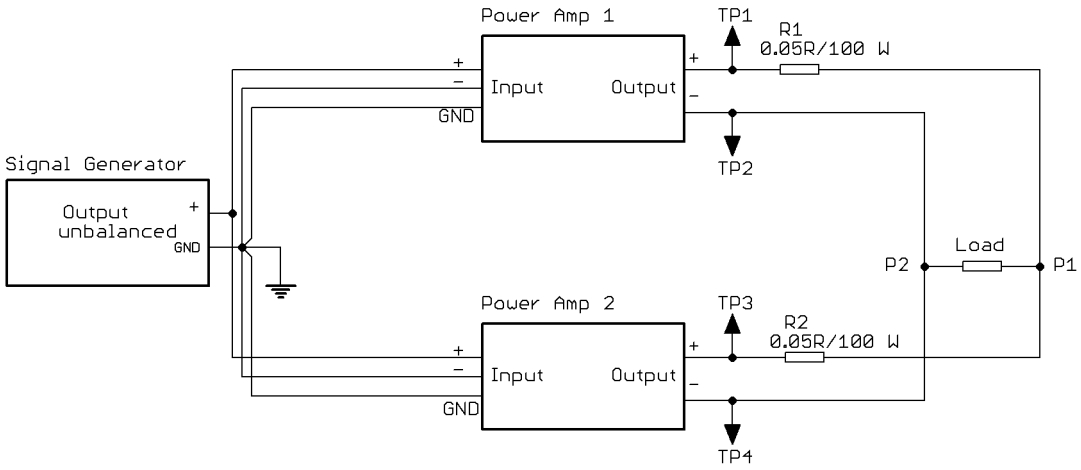

Figure 2: Amplifier System in Parallel Operation

Figure 2 illustrates the structure of a 2-amplifier parallel system. The procedure described below explains the adjustments required for stable operation of the system:

a) Connecting the amplifier to the mains; Do not actuate the inputs and outputs.

b) Check DC offset:

   Switch on the amplifier (amplifier on); Leave to warm up for 15 minutes; Using a multimeter, measure the DC offset voltages at the amplifier outputs between the points TP1/TP2 and TP3/TP4, respectively. The voltage should be < 1 mV at every amplifier. Otherwise, calibration is required.

c) Check gain:

   “Mute” the amplifier; Connect a signal generator to both amplifier inputs (as shown in Figure 2); set the DC signal to an amplitude of 1 V_{DC}; “Unmute” amplifier; Using a multimeter, measure 10 V_{dc} between the points TP1/TP2 and TP3/TP4, respectively. With deviations greater than **± 1mV**, calibration is required.

d) Verification of current distribution:

   “Mute” the amplifiers; Connect the ballast resistances R1 and R2 with the amplifiers and the load in accordance with Figure 1 (take into account the required cable cross sections; use minimum and equal cable lengths); Connect multimeter to the points TP1 and TP3; “Unmute” the amplifiers; At the signal generator, slowly adjust the DC amplitude from 0 V upwards to the maximum level in accordance with the application. While doing this, observe the voltage level at the millivoltmeter. With correct DC offset and gain, the voltage must not exceed 100mV. Otherwise, perform step b) and c) again or calibrate the amplifier.

After successful adjustment, the 2-amplifier parallel system is ready for operation. The procedure for larger systems is analog.

3 Increasing the voltage: Series operation

The equivalent of parallel connection is series connection of two identical voltage sources, see Figure 3. The voltage is doubled and the maximum obtainable output current corresponds to the value of each individual voltage source.

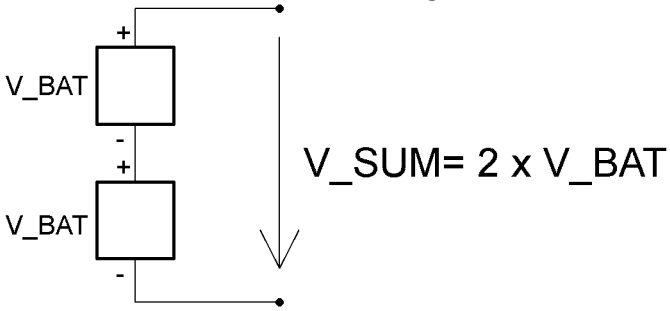

Figure 3: Two Batteries in Serial Configuration

A system with 2 amplifiers provides two different operating modes.

3.1 “Differential” mode

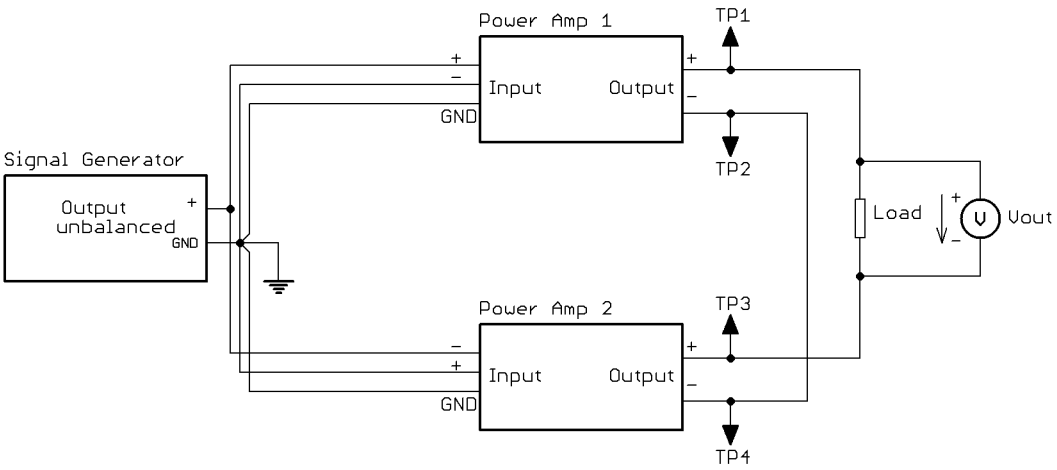

Figure 4: Differential Operation

Figure 4 illustrates the “differential” mode of two amplifiers, also referred to as “bridge mode”. The load is not connected to the signal ground; it “floats” between the (+) outputs of the amplifiers. This configuration can be easily built up with every model from the A1110-X-X product range without any additional accessories to obtain an operationally safe system.

For stable operation, the amplifier parameters gain and DC offset must be checked at the devices involved:

a) Connecting the amplifier to the mains; Do not actuate the inputs and outputs.

b) Check DC offset:

   Switch on the amplifier; Leave to warm up for 15 minutes; Using a multimeter, measure the DC offset voltages between the points TP1/TP2 and TP3/TP4, respectively. The voltage should be < 1 mV at every

amplifier. In case of excessive deviation of the values, calibration is required.

c) Check gain:

"Mute" the amplifier; Connect a signal generator to both amplifier inputs; set the DC signal to an amplitude of 1 V_{DC}; "Unmute" amplifier; Using a multimeter, measure 10 V_{dc} between the points TP1/TP2 and TP3/TP4, respectively. With deviations greater than **± 10mV**, calibration is required.

3.2 "Single-ended" mode

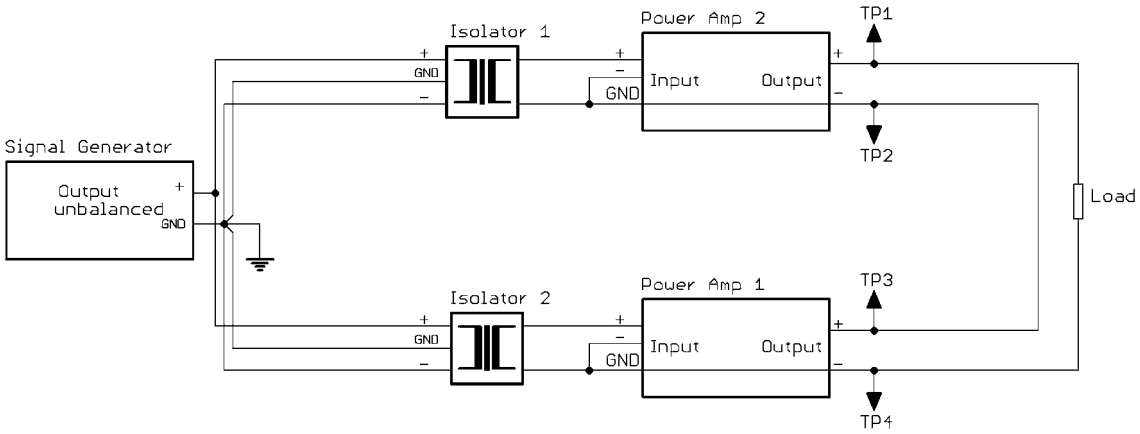

Figure 5: Single Ended Operation

Figure 5 illustrates the "single-ended" mode with to amplifiers. Here, the load is connected to the signal ground via the (-) output of amplifier 1: therefore, the output voltage is "ground-related". Since the (–) output of amplifier 2, i.e. its signal ground is connected to the (+) output of amplifier 1, the different signal grounds or reference potentials must be isolated using an isolation amplifier (isolator). This is also applicable for all other outputs (e.g. voltage monitor out)!
With this operating mode, it is not the load that "floats" (as is the case in "differential" mode) but amplifier 2. To ensure the required identical transmission behavior of all amplifiers involved, an amplifier 1 must also be an isolation amplifier.
Systems using more than two amplifiers must always be structured in "single-ended" mode.
With these scenarios gain and DC offset must also be checked prior to final commissioning as specified in 3.1.

4 Increasing the current and voltage: Parallel and series operation

The combination of two identical voltage sources connected in parallel and in series, respectively, as outlined in Figure 6, results in double the output current at double the output voltage.

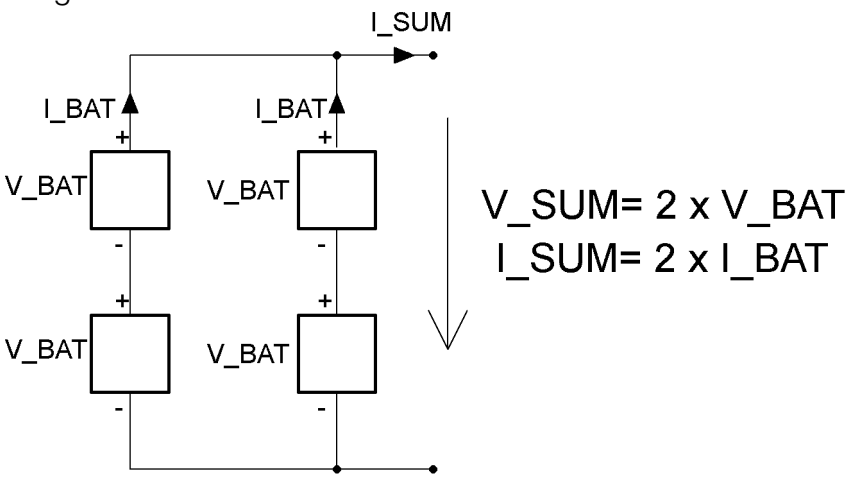

Figure 6: Serial and Parallel Operation

Figure 6 illustrates a system with 4 power and 4 isolation amplifiers in combined serial and parallel operation.

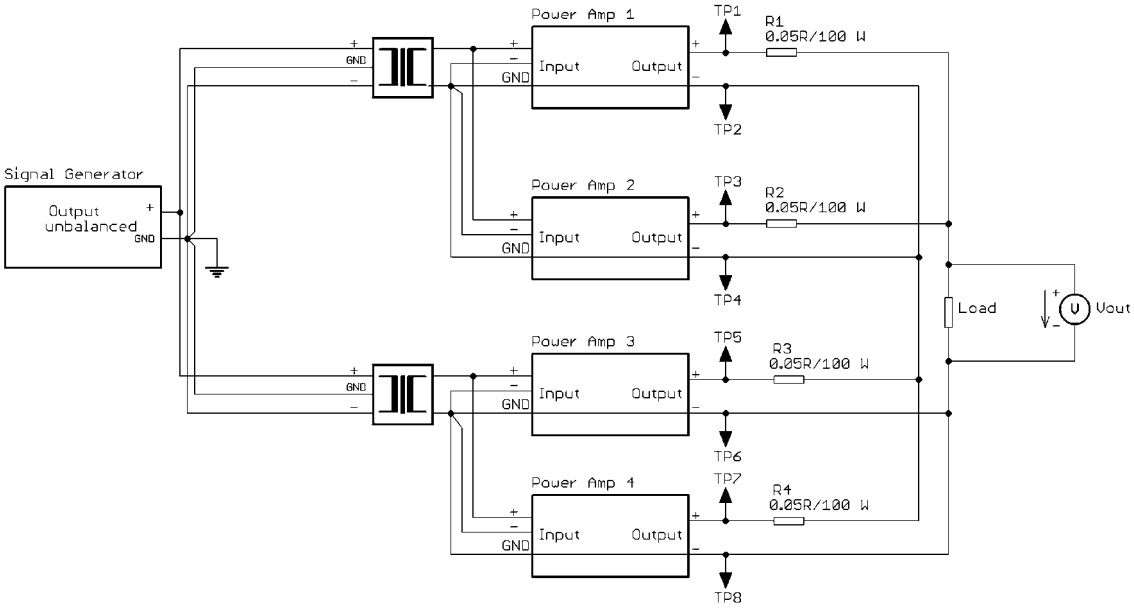

Figure 7: Two-Parallel / Two Series Single Ended Amplifier System

The DC offset and gain variables, which are important for stable operation, must be verified for every “participant” as is described in chapter 2 and 3.2. Subsequent to careful wiring, commissioning should be started with low signal levels (e.g. 100 mV/1kHz). Visual quality check of the output voltage would be reasonable to detect possible undesired inclination to vibration of the system. Naturally, not all problems that may be encountered during operation of the multi-amplifier systems can be discussed here.
But: Our support is just a phone call away!

5 Cables and more

5.1 Output wiring

An important aspect in structure design and ultimately also for stable operation of a multi-amplifier system is the cables required. They must be suitable for the expected currents and voltages in terms of cross section, length, insulation.

Continuous Current	Area	AWG
21 A	1.5 mm²	16
29 A	2.5 mm²	14
38 A	4.0 mm²	12
49 A	6.0 mm²	10
67 A	10.0 mm²	8
90 A	16.0 mm²	6
119 A	25.0 mm²	3

Table 2: Copper Wire Current Carrying Capacity in Free Air @ 25°C AT

Table 2 lists some cable cross sections with their maximum current-carrying capacity for two-wire, exposed lines (e.g. wired on walls/ceilings or in cable trays) with PVC insulation. When using single-wire cables they should be twisted if possible (inductivity minimization).
In all cases, the cables must be selected as short as possible and at equal lengths; This is an important aspect in multi-amplifier parallel systems, in which high currents can flow from the junction point of the ballast resistances to the load (see Figure 2: line from P1 or P2 towards the load).
The permissible voltage insulation strength is also important for cable selection. Particularly in multi-amplifier serial systems, the cable insulations must cater for the expected voltages.

5.2 Input wiring

For wiring of the signal inputs, shielded lines with low capacity (<60 pF/m) are a good choice. We recommend balanced, star-shaped signal wiring from the signal source for reduction of possible injected interferences (see also White Paper no. 4: Balanced Input). All models of the A1110-X-X product range are equipped with the required inputs.

5.3 Accessories

5.3.1 Aids for inputs

For building up a “single-ended” amplifier system, isolation amplifiers are required. These are available in the following versions:

- A1340-C1; 1-channel isolation amplifier for external use
- Option_05; 1-channel isolation amplifier, retrofitting kit for integration in devices from the A1110-X-X product range

5.3.2 Aids for outputs

- A1110-16-PX; connection box for amplifier parallel systems incl. connection cables and ballast resistances

Dr. Hubert GmbH
Universitätsstraße 142
44799 BOCHUM
GERMANY
Tel. +49 234 970569-0
Fax. +49 234 970569-29
sales@drhubert.de
www.drhubert.de