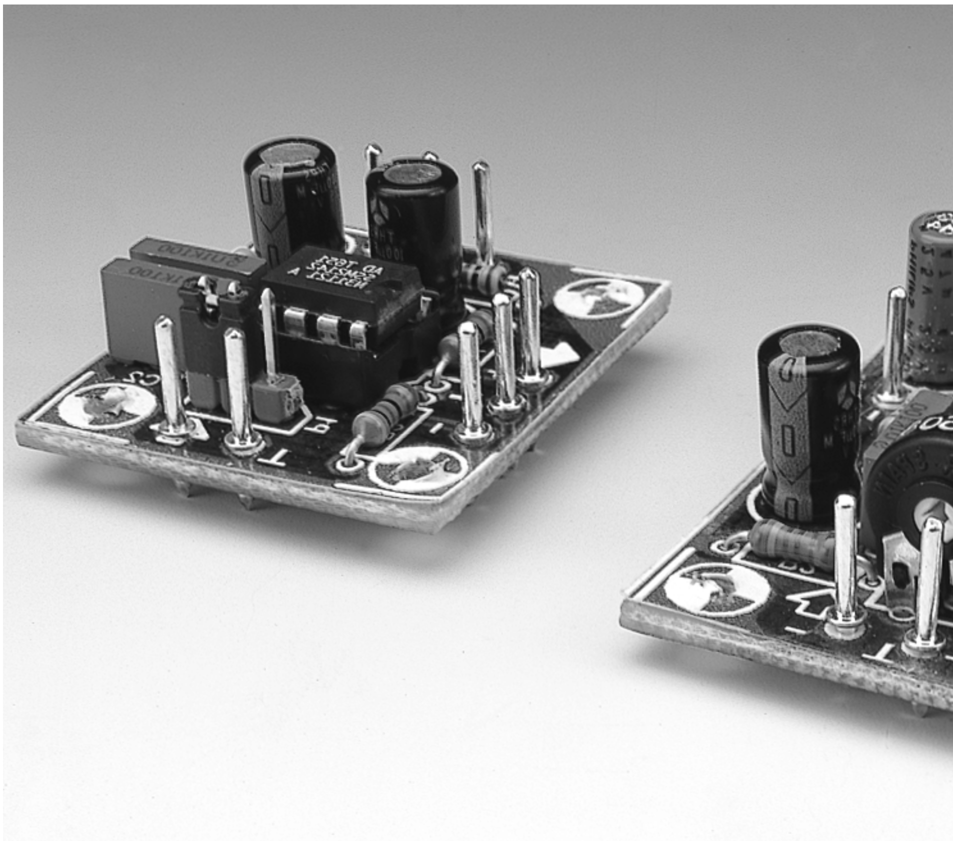
Contents

Balanced/unbalanced converters for audio signals

for high-end applications



In the Quest For Quality, a quasi-metaphysical activity zestfully practised by countless audiophiles, the use of 'balanced' (or symmetrical) signals is believed to contribute considerably to the end result. In this article we take pleasure in presenting balanced/unbalanced converters for audio signals. The designs, we are convinced, offer a solution to many problems you may stumble on when it comes to conveying small audio signals over large distances.

Design by J. F. Brangé

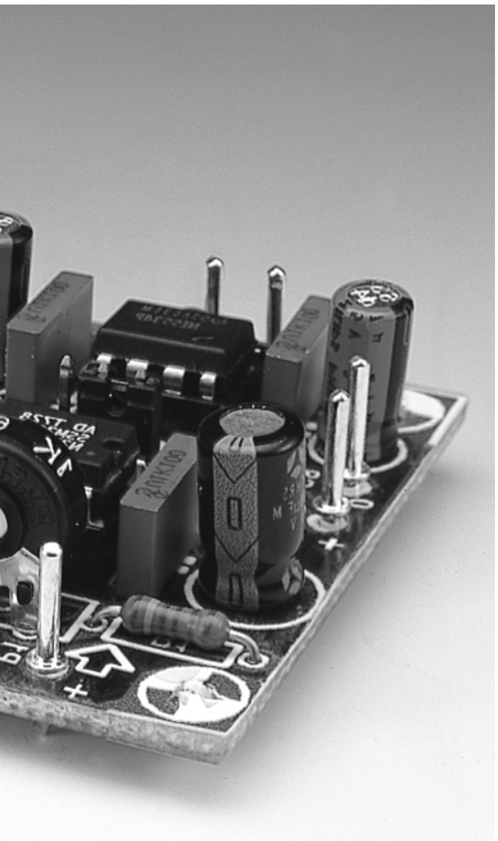
First things first. Let's recall that an unbalanced (asymmetrical) signal is defined as existing with respect to the ground line in a circuit. Consequently, conveying an unbalanced audio signal from one preamplifier stage to another by way of a cable may pose various problems including parasitics and radiation which degrade the quality of the audio signal. The use of shielded cable is an insufficient remedy, particularly when the signal source supplies low signal levels (say, a couple of millivolts).

The panacea in these cases is to make the signal balanced, that is, floating with respect to ground. Doing so allows a weak source signal to be conveyed over long distances (if necessary) without it being 'modified' underway. Sure, the problem of parasitics remains. However, the balanced signal being converted to unbalanced again at the input of the 'receiver', noise is effectively cancelled out by the differential effect. The floating signal on the two wires arrives at the inputs of the differential circuit. Whereas the wanted audio signal arrives with opposite phases on the two wires, any noise picked up by the symmetrical cable will have the same phase on the two wires. Consequently, this noise is effectively eliminated by the subtracting operation of the differential circuit.

There are, without doubt, many circuits which enable an audio signal to be converted from balanced to unbalanced and the other way around. The operational amplifier (opamp) lends itself quite well to this kind of operation. Provided you use quality audio opamps, ample results will be obtained. However, a couple of precautions should be taken to prevent degrading the performance that may be achieved in theory. One of these conditions is the use of 'hand picked' resistors with a tolerance of 0.1 per cent or better.

UNBALANCED-TO-BALANCED CONVERSION

There is a modern solution to this problem. Analog Devices has developed integrated circuits which are totally geared to this application. These ICs boast internal resistors which are laser-trimmed to a precision of 0.0001%! Not surprisingly, these ICs achieve ‘professional-grade’ performance as far as noise rejection, parasitics suppression and distortion are concerned. These ICs now being relatively well distributed in Europe, we have few hesitations about presenting you practical circuits for a stereo application. Obviously, the two stereo channels being identical, it will be sufficient to describe only one of these.



The circuit diagram of the unbalanced-to-balanced converter is shown in **Figure 1**. The SSM2142 opamp from Analog Devices is a buffer/amplifier with an internal differential output driver. Its main function is to convert an unbalanced input signal into a high-level balanced signal. Based on an electronically balanced cross-coupled chip topology, the SSM2142 comes close to achieving the performance of balancing circuits that make use of a transformer for line driving. As a matter of course, the IC has the advantage of a much smaller footprint than that of a transformer, while offering comparable common-mode rejection. Those of you who are interested in the chief technical specs of the SSM2142 will no doubt find this month’s *Datasheet* pages of particular interest.

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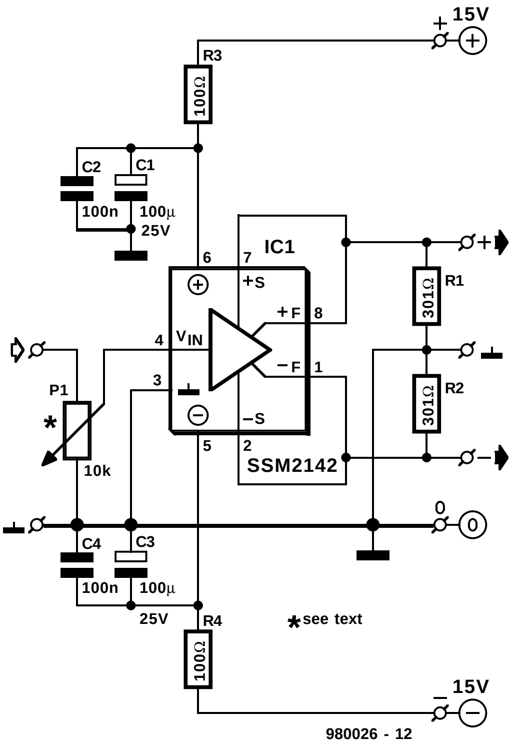

The input signal is applied to the chip via a 10-kΩ preset, P1, whose function is to adjust the output signal level while also matching the IC input impedance recommended by the manufacturer. The preset may, of course, be replaced by either a potentiometer with the same value, or a 3-way pinheader on to which a jumper is

Figure 1. Circuit diagram of the unbalanced-to-balanced converter based on the SSM2142 from Analogue Devices.

Figure 2. The balanced-to-unbalanced converter is designed around the SSM2141 and an NE5534 buffer opamp.

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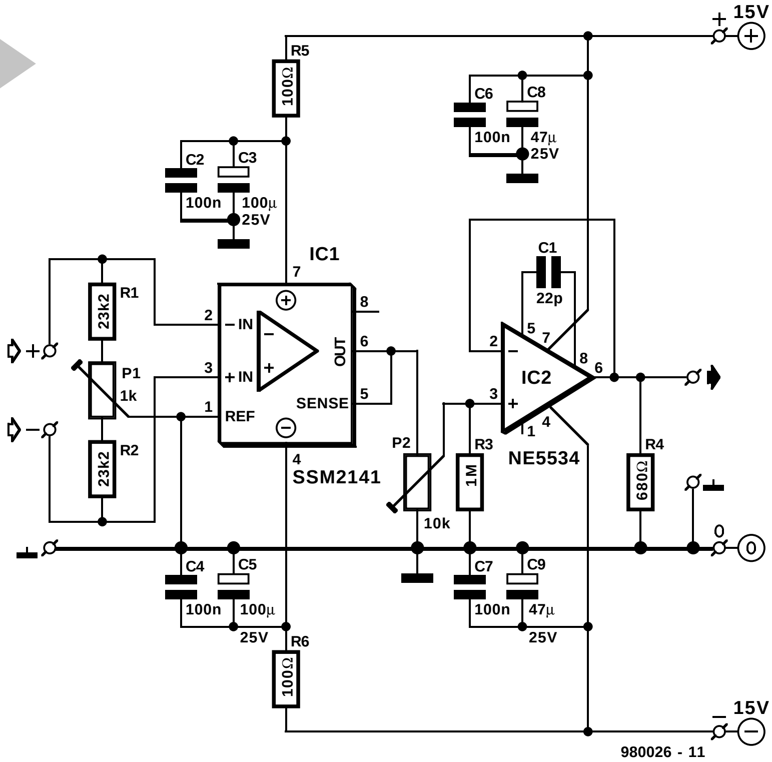

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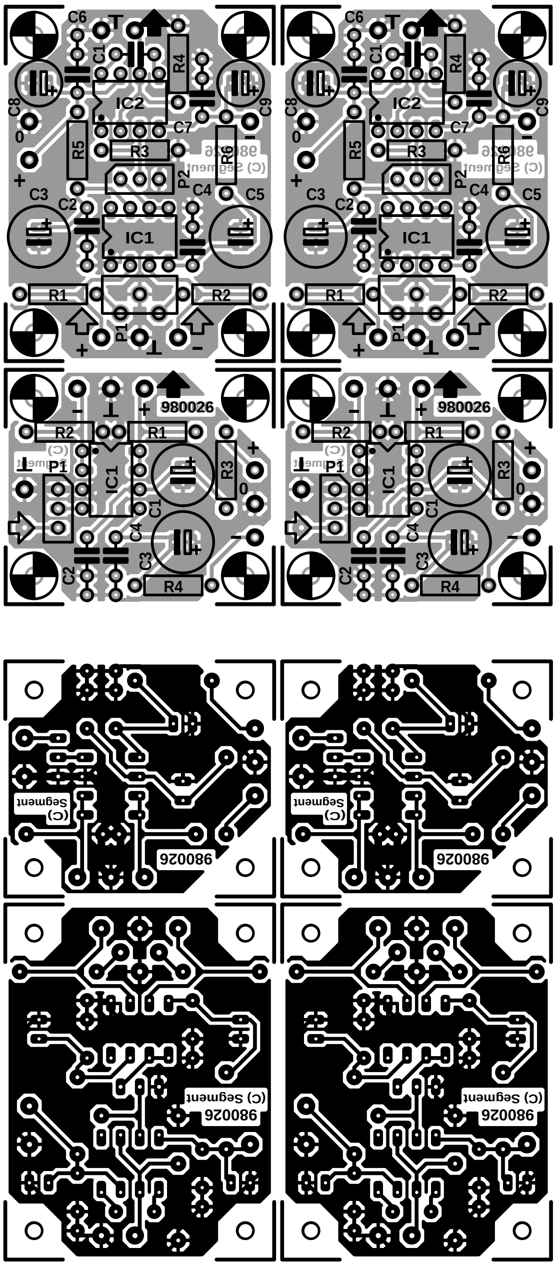

Figure 3. Copper track layout and component mounting plan of the printed circuit board designed for two balanced-to-unbalanced converters and two unbalanced-to-balanced converters (board available ready-made through the Readers Services).

installed which takes the signal from the 'input' pin to the centre pin. This is the solution we adopted. The output is also simple: pin 8 of the SSM2142 supplies in-phase (+) output signal, while pin 1 supplies the inverted (–) signal. Since both outputs are loaded with a 301-Ω resistor to ground, an output impedance of about 600 Ω is created.

The SSM2142 is protected against parasitic signals arriving by way of the supply lines. This is achieved by connecting elementary RC filter networks comprising of R3-C1-C2 and R4-C3-C4 to the respective supply pins of the SSM2142. The output of the circuit supplies an audio signal which should be worthy of the very best home-brew audio projects.

A final word or two about the power supply: although a ±12 V symmetrical supply will be fine in many cases, we recommend using ±15 V as shown in the circuit diagram because that value results in an improved dynamic range. The absolute maximum supply voltage is ±18 V.

BALANCED-TO-UNBALANCED CONVERTER

For this purpose you need the SSM2141. This IC, a direct relative of the SSM2142, is an integrated differential-amplifier designed to receive balanced 'line' signal levels in audio

Figure 4. Finished prototype of each of the converters.

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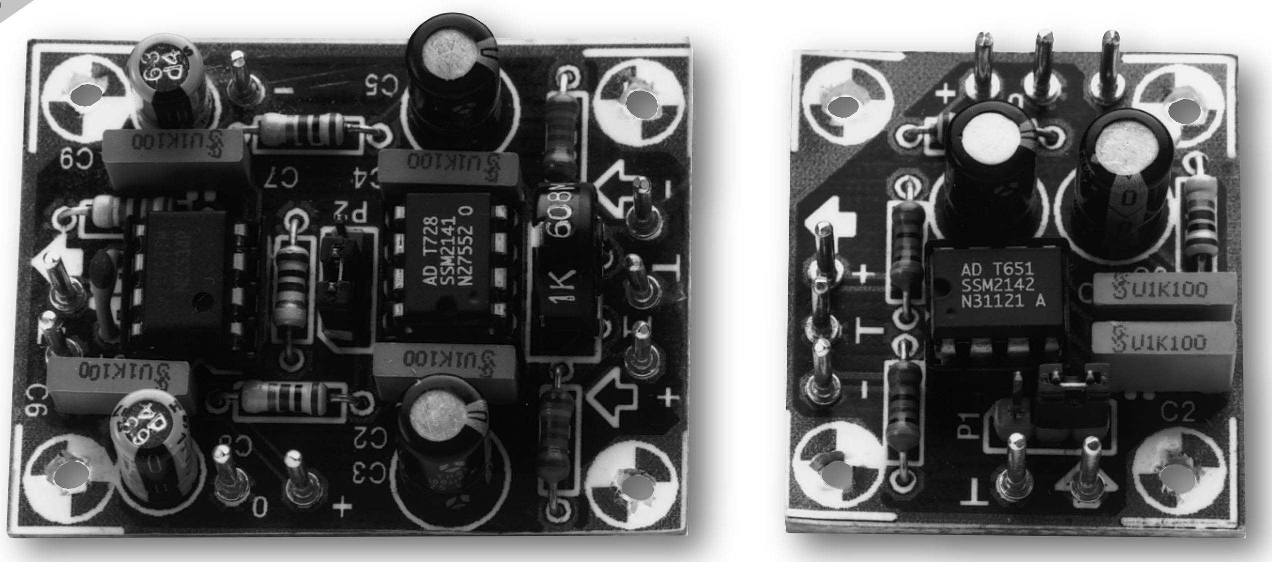

COMPONENTS LIST

Printed circuit board: order code 980026-1.

Balanced-to-unbalanced converter

Resistors:
R1,R2 = 23kΩ22 1%
R3 = 1MΩ
R4 = 680Ω
R5,R6 = 100Ω
P1 = 1kΩ preset vertical
P2 = 10kΩ logarithmic potentiometer (may be replaced by jumper)

Capacitors:
C1 = 22pF
C2,C4,C6,C7 = 100nF
C3,C5 = 100µF 25V radial
C8,C9 = 47µF 25V radial

Semiconductors:
IC1 = SSM2141 (Analog Devices)
IC2 = NE5534 (Philips Semiconductors)

Unbalanced-to-balanced converter

Resistors:
R1,R2 = 301Ω 1%
R3,R4 = 100Ω
P1 = 10kΩ logarithmic pot (or jumper)

Capacitors:
C1,C3 = 100µF 25V radial
C2,C4 = 100nF

Semiconductor:
IC1 = SSM2142 (Analog Devices)

circuits requiring high noise immunity and common-mode noise rejection. This IC achieves a typical CMR (common-mode rejection) spec of 100 dB. By comparison, an opamp with four regular resistors around it will be hard pressed to achieve a CMR rating of anything over 40 dB or so, which is by no means enough for high-end audio designs. Let's cast a look at **Figure 2** which shows the schematic of this sub-circuit. The resistor networks between the SIG+ (pin 3) and SIG– (pin 2) inputs of the SSM2141 fix the input impedance at about 47 kΩ. Preset P1 (1 kΩ) allows the CMR value to be fine-tuned (see also further on). This component is optional, however, and may be omitted. As indicated by the component overlay of the balanced-to-unbalanced converter, it may be replaced by wire links. This was also done on our prototype. Note, however, that the source impedance has to be perfectly controlled, as the slightest imbalance of the source resistance will reduce the achievable CMR value. For example, a difference of just 5 Ω is punished with a CMR increase of no less than 20 dB.

The output signal of the SSM2141 is applied to an NE5534 voltage follower by way of a 10-kΩ preset. The (low-impedance) output of the NE5534 should be able to drive almost any pre-amplifier input. The remarks on the supply filtering of the SSM2142 also apply to the SSM2141.

If used, the CMR fine-tuning preset has to be adjusted with the aid of a differential input signal. What better way to generate such a signal than use the SSM2142? Apply a 50-Hz, 100-mV signal to the input of the 2142. Connect its output signal to the 2141. Next, tweak P1 for the smallest possible signal at the output. This setting corresponds to the best possible CMR. Those of you who do not have an oscilloscope (or access to one) may replace the 1-kΩ preset by two wire links, as mentioned earlier. If you can get hold of two 23.2-kΩ resistors with a tolerance of 0.1%, no adjustment should be necessary.

As already mentioned, the circuits are powered by a ±15-V symmetrical supply. Current consumption being very modest indeed, you can make do with a mains adaptor with stabilized ±15 V outputs.

CONSTRUCTION

As you can see from the artwork in **Figure 3**, a printed circuit board was designed for the two converters. The artwork comprises the copper track layout and the component mounting plan (overlay). The PCB design for each converter is duplicated so you need just this one board for a stereo application.

As a matter of course, it is best to start by separating the four small boards. The two smaller boards are used to build the unbalanced-to-balanced converters, while the boards with two IC sockets on them are intended for the balanced-to-unbalanced converters. Neither of these circuits should present undue difficulty when populating the boards. The only points to be made here are to observe the polarity of the electrolytic capacitors and the orientation of the integrated circuits when they are inserted into their sockets. Also be sure not to mix up the two 8-pin integrated circuits on the balanced-to-unbalanced converter board.

The large unetched copper areas on the boards acts as ground planes which help to make the circuits immune to noise and other stray signals.

Having finished the construction of the converter boards you may mount them in small boxes, and wire them up to the external parts. The input and output connectors may be mini-DIN types of which only three pins are used. The unbalanced-to-balanced converter is best located close to the signal source. Its complement, the balanced-to-unbalanced converter, will typically be installed near the 'receiver'. Note the connections: the outputs of the unbalanced-to-balanced converter are the mirror-image of the inputs of the balanced-to-unbalanced converter.

The circuits should function spot-on. The photograph in **Figure 4** should allow you to compare your own efforts at building the circuits with those of our engineering laboratory. In particular, you should be able to detect missing components immediately in the (unlikely) case of a problem.

A final note aimed at those with a keen interest in figures: Below are the very encouraging results of exhaustive measurements on a pair of these converters built up in our design lab:

- unbalanced-to-balanced converter: THD (total harmonic distortion) between 0.0008% and 0.0015% from 20 Hz to 20 kHz.
- balanced-to-unbalanced converter: THD between 0.0008% and 0.0011% from 20 Hz to 20 kHz; CMR between –140 dB and –70 dB from 20 Hz to 20 kHz.

All measurements were made with an Audio Precision test system.

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