How to Power and Connect Professional Condenser Microphones

1. **A condenser microphone is comprised of a transducer (capsule) and a microphone amplifier. The microphone amplifier is usually powered through the cable, by a circuit in the equipment to which it is connected.**

Condenser microphone transducers operate at such a high impedance that they cannot even be connected to a cable without active impedance-matching circuitry. This matching function is accomplished by the microphone amplifier.

The amplifier is essentially no more than an impedance converter. In professional practice, its operating current or "powering" is supplied through the microphone cable. Internal batteries, if used in a high-output microphone, would need rather frequent checking and replacement.

Microphone powering circuitry is often built into studio equipment (e.g. consoles and mixers). Where this is not the case, batteries or AC-powered supplies must be used. (Figure 1)

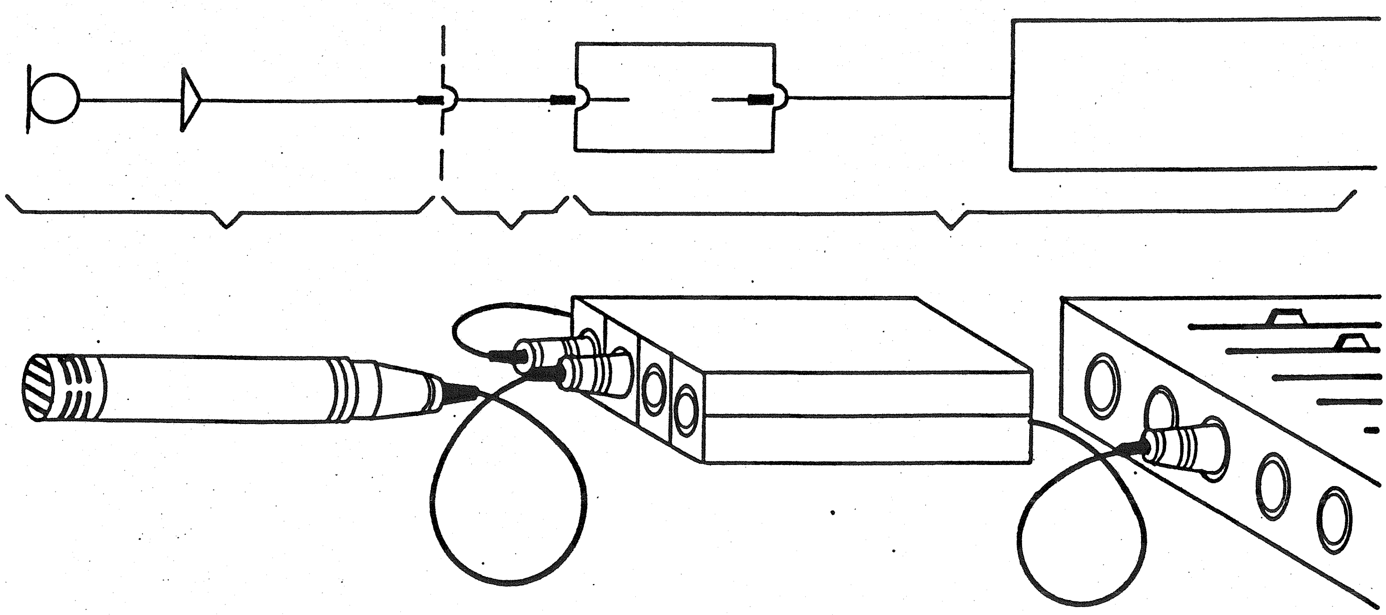


Figure 1. Connecting a professional condenser microphone.

2. Powering is accomplished by various circuit methods.

When the first transistorized condenser microphones were being developed, their designers sought a means of powering them through the signal cable so that standard two-conductor shielded cable could be used for all microphones. The various manufacturers each devised solutions which have been in competition with one another for quite some time.

2.1 Parallel powering

With parallel powering, the operating voltage is placed across the two modulation leads of the cable. This powering method is not often found in studios today.

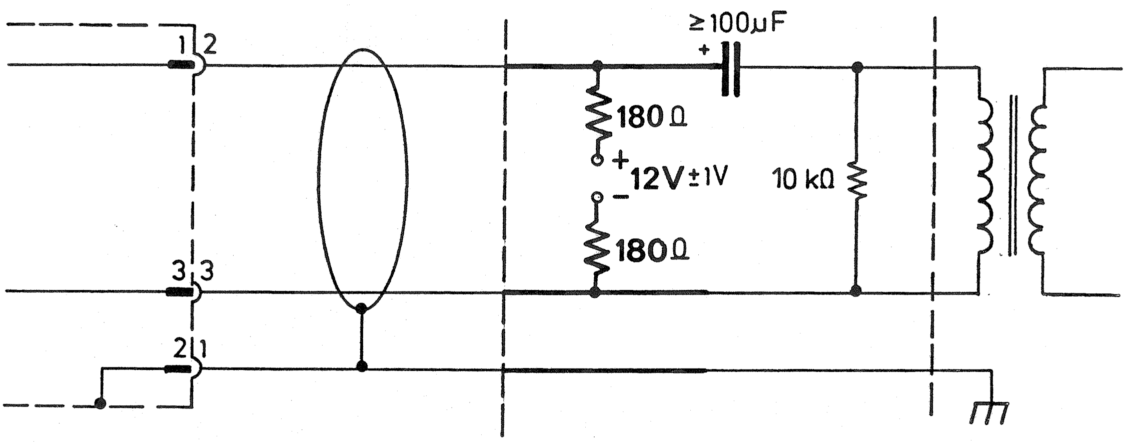


Figure 2. Parallel powering.

Figure 2 shows the circuit as given in DIN standard 45595. Particular characteristics of parallel powering include the following:

2.1.1 It should always be possible to shut off the powering.

In order to use a dynamic microphone on an input which was designed for a parallel-powered condenser microphone, the powering must be turned off. Dynamic microphones cannot withstand DC across their modulation terminals. (The DC must be decoupled at some point from the input of the console or recorder as well.)

2.1.2 Good power supply filtering is important; mutual decoupling of multiple microphones is recommended.

The power supply voltage must be very well filtered, since it is superimposed upon the signal voltage. Any hum or other noise in the supply circuit will become part of the audio signal. If several microphone channels are being fed from one source of supply voltage, separate filtering for each microphone will reduce any cross-coupling among them.

2.1.3 Unbalanced operation is simple.

Since the cable shield is not a part of the supply circuit, one of the modulation leads may simply be connected to ground. Unbalanced operation is thus very simple; no transformer is needed.

According to DIN standard 45595, however, one side of the supply may also be internally grounded to improve the symmetry of the audio signal. If such a circuit is used with an unbalanced input, one of the feed resistors would be effectively short-circuited. But any possible disadvantages of this situation can easily be avoided, as outlined in section 3.3.1.2.1.

2.1.4 Signal phase and DC polarity are linked.

Another characteristic of parallel powering is that the modulation leads may not be reversed anywhere between the microphone and its power supply, since the powering would then be reversed also. This might be considered a disadvantage since it means that signal phase can only be corrected, if required, somewhere after the signal comes out of the power supply. On the other hand, it offers the advantage that the phase orientation of the microphones can always be assumed to be correct, because the powering would not function at all if the wires were crossed.

2.2 Phantom powering

With the phantom powering method, the positive pole of the power supply is connected to both modulation leads through a pair of matched resistors; the current returns through the cable shield (Figure 3). This is the most commonly encountered method for powering condenser microphones in studios. DIN 45596 sets forth certain standard component values for various supply voltages.

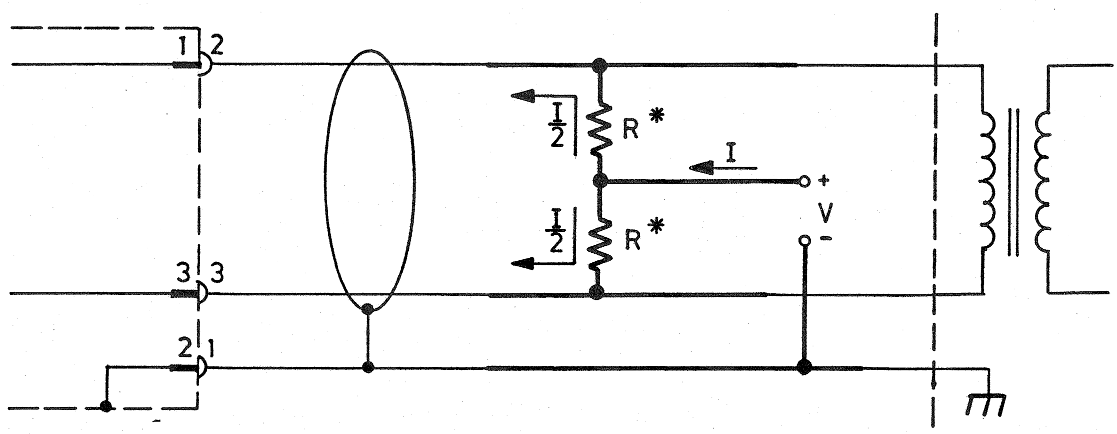


Figure 3. Phantom powering

*Tolerance: ± 20%, but the **difference** between the two resistors must be **less than 0.4%** for adequate symmetry and to prevent harmful DC from flowing between the two modulation leads.

V	R	I_{max}
+48 V	6.8 kOhms	10 mA
+12 V	680 Ohms	15 mA

The definition of a maximum current is not really necessary. From a safety standpoint, the feed resistors ought to be able to withstand the full short circuit current. Earlier standards set a much lower limit on supply current (2 mA for 48 Volts), due to certain historical circumstances which are not nearly so compelling today.

Further characteristics of phantom powering are:

2.2.1 No DC appears between the modulation leads of the cable; safe for dynamic microphones

As long as the two feed resistors are selected to be exactly equal and there is equal current flow in the two modulation leads, the voltage drop across the feed resistors will match. Consequently, there will be no DC potential difference between the two modulation leads. The input transformer, if one is used in the mixer or recorder, can usually be connected directly. The power supply furthermore does not need to be turned off when dynamic microphones are used; they will draw no current.

2.2.2 High immunity to interference; no need for decoupling among microphones which are powered from a common source of supply current

The powering method does not impose a voltage between the modulation leads; thus any variations in the supply voltage (within the amplifier's tolerances) will not affect the signal. Power supply ripple is not especially critical; 1 mV is usually tolerable even though this is hundreds of times greater than the microphone's own noise level.

Interference induced into the cable shield, being effectively in series with the supply current, is likewise suppressed some 60 dB or more. For the same reason, there is no need for special decoupling circuitry when several microphones are being powered from the same source of supply current.

2.2.3 The necessary precondition for the proper functioning of phantom powering: feed resistors which are matched to within 0.4%

The advantages of phantom powering as described above depend on equal current flow in the two modulation leads, and on the feed resistors being exactly equal in value. In practice, component tolerances must be taken into account.

DIN 45596 and the IEC standard state that the difference between the actual feed resistor values shall not exceed 0.4%. Thus even 1% resistors are inadequate, because a difference of up to 2% could exist between a pair of them.

It is up to the microphone manufacturer to ensure that the microphone will draw equal current from the two modulation leads. But the feed resistors are usually built into the mixing desk or recorder, so the responsibility for the match between them rests with its maker.

If the feed resistors are poorly matched, an input and/or output transformer could become magnetized (2.2.3.1), and the susceptibility of the system to interference will increase (2.2.3.2).

2.2.3.1 DC offset and/or permanent magnetization of transformers due to unequal feed resistors

As figure 3 shows, the signal from a microphone is usually connected directly to the input transformer of a mixing desk. To prevent any DC from flowing in the primary winding of the transformer, the two feed resistors would have to match exactly. The actual limit of permissible DC depends on the size of the input transformer. If a microphone uses an output transformer, it too can be similarly affected. However, most condenser microphones with output transformers use relatively little current, so that any DC offset would tend to be smaller.

One possible means for preventing magnetized input transformers would be the use of coupling condensers. The disadvantages would include increased cost and a somewhat decreased signal-to-noise ratio (unweighted), since the input impedance would rise at low frequencies.

2.2.3.2 Increased sensitivity to interference and/or reduced common mode rejection due to mismatched feed resistors

Even if coupling capacitors are built in (as in 2.2.3.1) or the console inputs are transformerless, the feed resistors must still be matched in order to maintain the degree of immunity from cable-induced interference that is expected from balanced circuitry.

If we stipulate a 60 dB rejection of such "common mode" interference, we will arrive at the above-mentioned requirement to keep the resistor values within 0.4% in each pair.

3. Connections

3.1 Impedances

A distinction must be made between the source impedance of the microphone and the impedance of the load. Microphones work best under "open circuit" conditions.

The source impedance is the internal (generating) impedance of the microphone; the load impedance is the input impedance of the equipment into which the microphone is sending its signal (Figure 4).

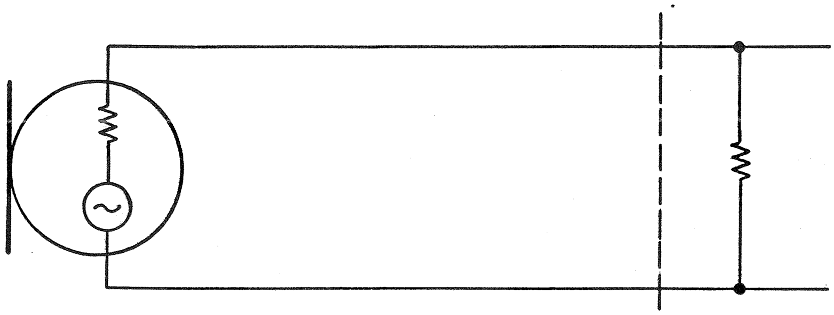


Figure 4. Source Impedance and Load Impedance

If the load impedance were to equal the source impedance of a microphone, the resulting voltage divider could have unforeseen effects on the frequency response since its particular capacitive, inductive, and resistive components are undefined. In a purely resistive circuit, there would be a loss in signal level of 6 dB. Since the noise voltage would decrease by some lesser amount, however, the signal-to-noise ratio would be reduced.

A further reason to make the load impedance as high as possible is that the electronics of the amplifier can deliver only a relatively small amount of power. A load impedance that is too low would restrict the maximum voltage level which the microphone could deliver without significant distortion. This would unduly limit its ability to respond to high sound pressure levels.

3.1.1 Microphone source impedance

The internal impedance ("source impedance") of a professional microphone should be as low as possible, to reduce the effects of induced interference.

Microphone source impedance values lower than 150-200 Ohms are rarely encountered, because the transformers (or the coils of dynamic systems) would give too low an output voltage level.

Semiconductor circuitry is able to accomplish more in this respect, delivering high signal levels even at very low impedance. This is clearly the ideal, but caution is advisable due to certain exceptional situations. There do exist some microphone inputs, mostly (but not exclusively) in equipment which is not of the highest quality, which have linear frequency response only when driven by an impedance of 150-200 Ohms. This can result from the input transformers being too small, or from feedback being returned to the input stage. The solution to this problem is simple: series resistors are connected symmetrically in the modulation leads, such that the resultant source impedance is effectively 150-200 Ohms. Naturally, it is better to use equipment which does not require this.

3.1.2 Load impedance

The input impedance of the equipment to which the microphone is connected forms the load impedance for the microphone; it should be as high as possible. The manufacturer's rated minimum load impedance should be observed.

For low-impedance microphones (as set forth in 3.1.1), 600 Ohms is generally high enough. (This impedance should also be maintained at low frequencies.) Fortunately, most so-called "200 Ohm" inputs are actually much higher than 200 Ohms. That terminology is usually (but not always) meant to indicate that the input was designed for the output level of a typical 200 Ohm dynamic microphone.

3.2 Reduction of the output level

If a condenser microphone is to be connected to an input designed for dynamic microphones, a reduction of its output level may be called for.

Professional condenser microphones deliver higher signal levels than dynamic microphones for the same sound pressure level. The difference may amount to 20 dB or more. This can lead to overload distortion at the input of the mixer or recorder, which would naturally be most apparent on signal peaks.

"Popping" on plosive consonants, especially words containing the letter "p", thus does not always indicate a defective microphone or an inadequate windscreen.

A reduction in signal level can be brought about simply with a "pad" circuit. But the minimum load impedance, as discussed in 3.1.2, should be maintained (figure 5a).

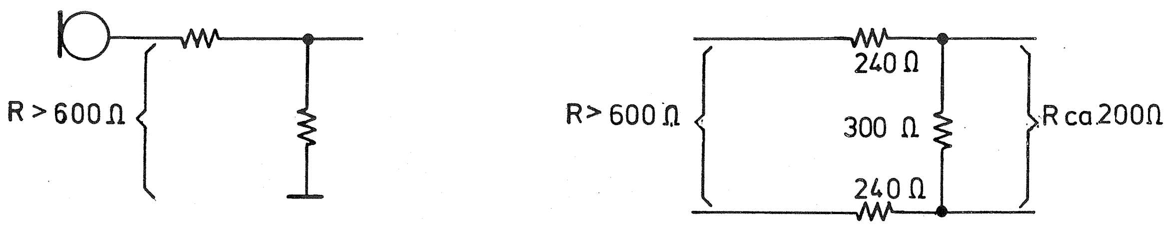


Figure 5. "Pad" circuits

In the professional realm, the pad circuit should be formed symmetrically, as shown in figure 5b.

With parallel-powered condenser microphones, the reduction in level can be carried out only after (or within) the power supply (Figure 6). A pad placed in the microphone cable would interfere with the powering.

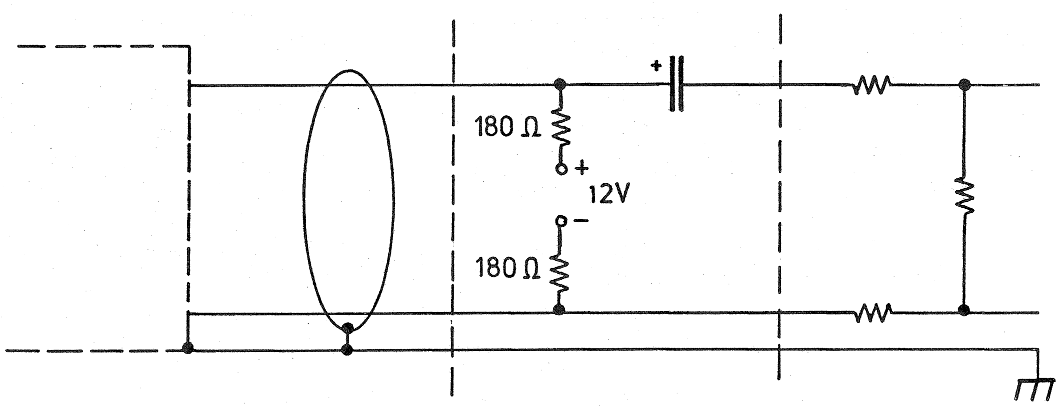


Figure 6. Level reduction for parallel-powered microphones

With phantom-powered condenser microphones, the reduction in level can be brought about at any desired point between the microphone and the equipment to which it is connected. The resistors of the "pad" circuit do not significantly restrict the operating current of the microphone (Figure 7a). But these resistors must also be in matched pairs to maintain the balanced circuit.

In general, for minimizing interference it is preferable to put the "pad" resistors after what might be a long run of microphone cable (figure 7b). This allows the signal to remain at the higher level for as much of the cable run as possible.

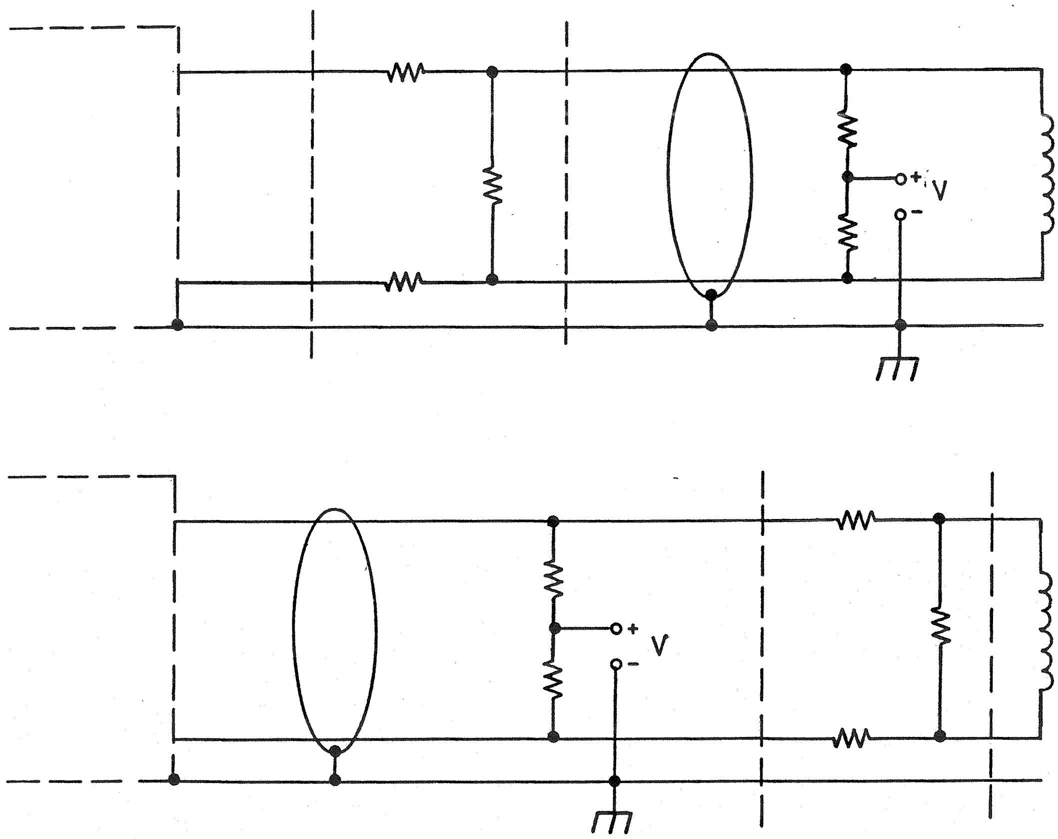


Figure 7. Level reduction for phantom powered microphones

3.3 Connection to unbalanced circuitry

Transistorized condenser microphones may not be connected casually to unbalanced inputs.

In studio practice, balanced microphone lines are usually used in order to help neutralize interference which could break into the cable. This technique is always the preferred one.

In semiprofessional applications, however, the low impedance of the microphone lines will usually give adequate protection. Thus unbalanced inputs are often encountered.

3.3.1 Connecting parallel-powered microphones to unbalanced inputs

It is usually no problem to connect parallel-powered microphones to unbalanced inputs without using a transformer.

There are several circuits for the use of parallel-powered microphones with unbalanced inputs:

3.3.1.1 Parallel powering with "floating" power supply

If the parallel powering circuit is as shown in Figure 2, an unbalanced signal may be obtained by connecting the shield with either one of the modulation leads.

This will not cause any harmful side effects. In principle it does not matter which modulation lead is grounded. However, it will usually be the negative lead, so that the positive lead with its positive signal phase will be the "hot" lead.

3.3.1.2 Parallel powering when one side of the voltage supply is grounded

If one side of the power source in a parallel-powering system is already grounded, grounding one of the modulation leads will cause a partial short circuit, the effects of which must be taken into consideration.

One pole of the voltage supply is usually grounded (internally), since this produces an advantageous symmetry of the audio signal with respect to ground. The negative pole will usually be the one which is grounded whenever power is drawn from the operating supply of the other equipment with which the microphone is being used.

To decouple the DC from the input of the mixer or recorder, either one or two capacitors can be used. The use of two capacitors has the disadvantage that with unbalanced connection, one of the feed resistors will be bridged only for AC. (3.3.1.2.2, Figure 10) Thus the possible operating conditions for the case with only one capacitor must be described. It should be placed in the modulation lead whose feed resistor is not at ground potential.

3.3.1.2.1 DC and AC short circuiting of one feed resistor

If one feed resistor is shorted by grounding a modulation lead, there will be no serious consequences (figure 8). Thus it is best to ground the lead for which the corresponding feed resistor is also grounded in the power supply.

Figure 8.
Short-circuited feed resistor, caused by unbalanced connection.

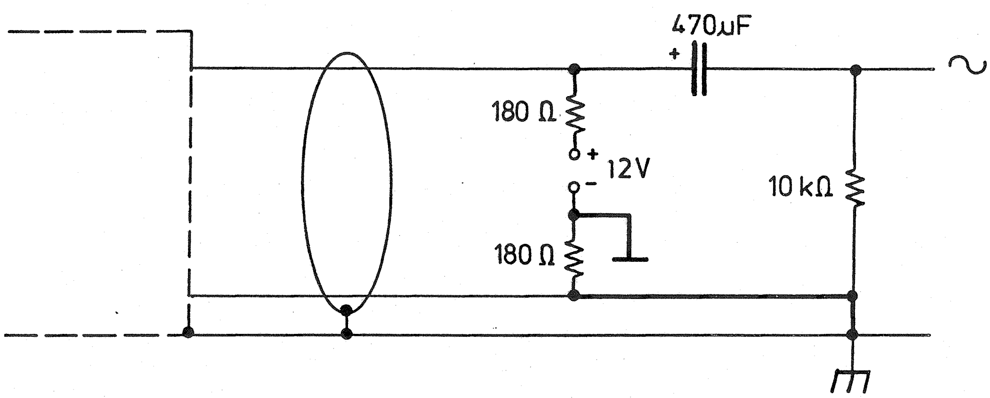
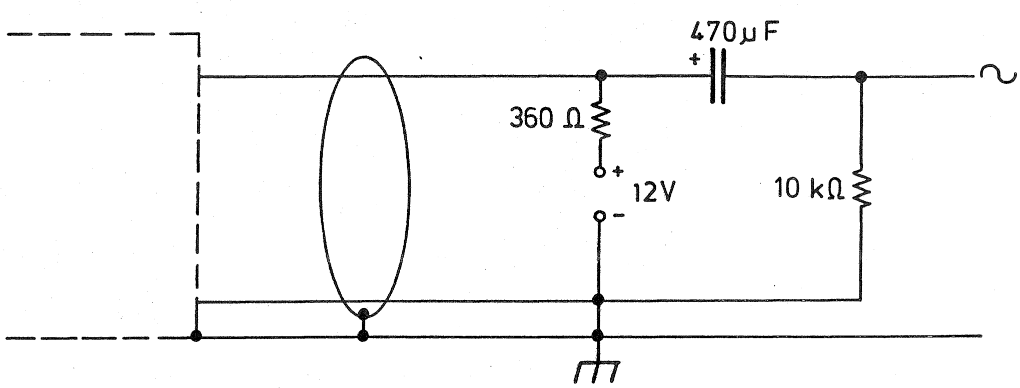


Figure 9.
Parallel powering for unbalanced use; a single-conductor shielded cable would also be sufficient.



This feed resistor is thus bypassed, and the current drawn by the microphone will increase by some minor amount. The maximum undistorted output level of the microphone will decrease slightly (around 1 dB in the case of a SCHOEPS CMC 4--), since the remaining feed resistor will load down the microphone. But the feed resistor does not have exactly the same effect as a load resistor, since the operating current is flowing through it too. To avoid these slight changes in current and maximum level, a circuit such as the one shown in figure 9 can be used. The powering is fed through the lead which is not grounded, through twice the normal feed resistance. This restores the normal DC circuit conditions, and the output signal is unbalanced.

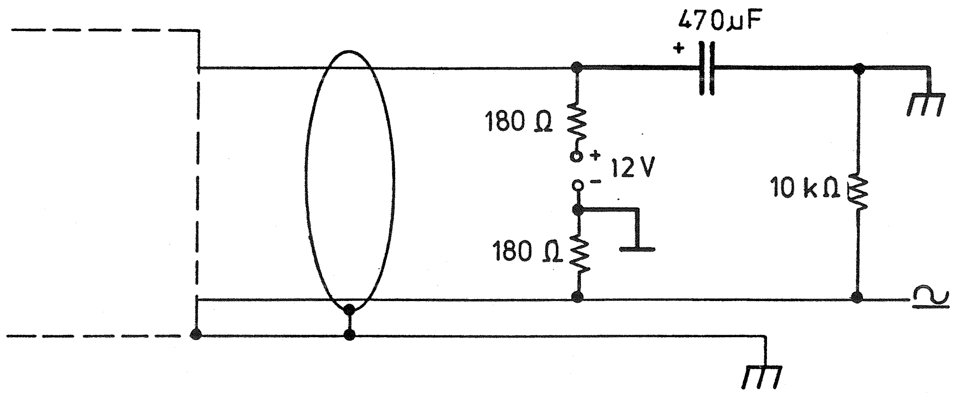


Figure 10. Capacitive shunting of one feed resistor, caused by unbalanced connection

3.3.1.2.2 Capacitive shunting of one feed resistor

The lead which contains the DC-blocking capacitor is the less appropriate one for grounding.

Doing so would capacitively bypass one feed resistor, loading down the microphone more but not offering a compensating increase in operating current as in 3.3.1.2.1. The maximum undistorted output level (headroom) would thus be decreased (by around 4 dB in a SCHOEPS CMC 4--). (Figure 10)

In addition, the signal lead would still carry part of the supply voltage, which would then be fed to the load. This could overload a direct-coupled input stage and block it entirely from functioning. (Example: Sony PCM-F1). The use of a second coupling capacitor could prevent this from happening, but the above-mentioned disadvantage of the capacitive bypassing would be unavoidable.

3.3.2 Connection of phantom-powered microphones to unbalanced inputs

The possible ways of connecting phantom-powered microphones to unbalanced inputs cannot be treated summarily. The best solution is to make the input symmetrical by the use of a transformer or other suitable circuitry.

The transformer should be as large as possible, and is least critical if its turns ratio is 1:1. It should be specifically designed for low source impedances. A 200 Ohm:200 Ohm type is suitable, for example. Note that it should be terminated not with 200 Ohms but with a resistance greater than the minimum load impedance (usually 600 Ohms; see also 3.1.2).

It is quite practical to build the transformer into the power supply unit. The SCHOEPS NG-- series supplies allow space for this. The quality of in-line cable transformers and similar small-format components is often unsatisfactory for use with professional condenser microphones.

Transformerless circuit modules for balanced input are available on the market today. They can be of very high quality, but they require an extra power supply. The input must be provided with protective circuitry (zener diodes are usually adequate), to ensure that the charge on the blocking condensers will not be dumped into it in the event of a cable short-circuit (see manufacturers' instructions).

3.3.2.1 Phantom-powered microphones with output transformers can be connected to unbalanced inputs.

The powering must be provided normally through both modulation leads; blocking capacitors are also placed in both. Either one may then be grounded, preferably such that the lead which is in positive phase becomes the "hot" lead (figure 11).

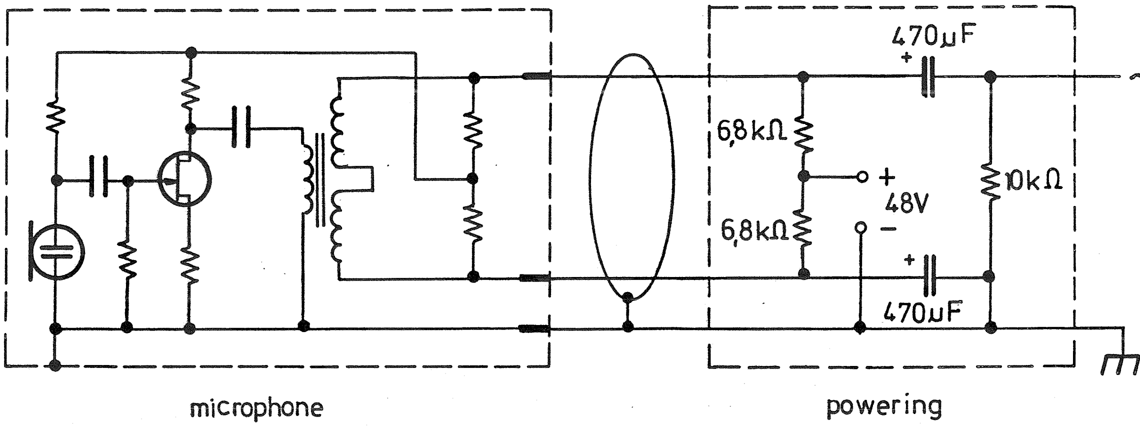
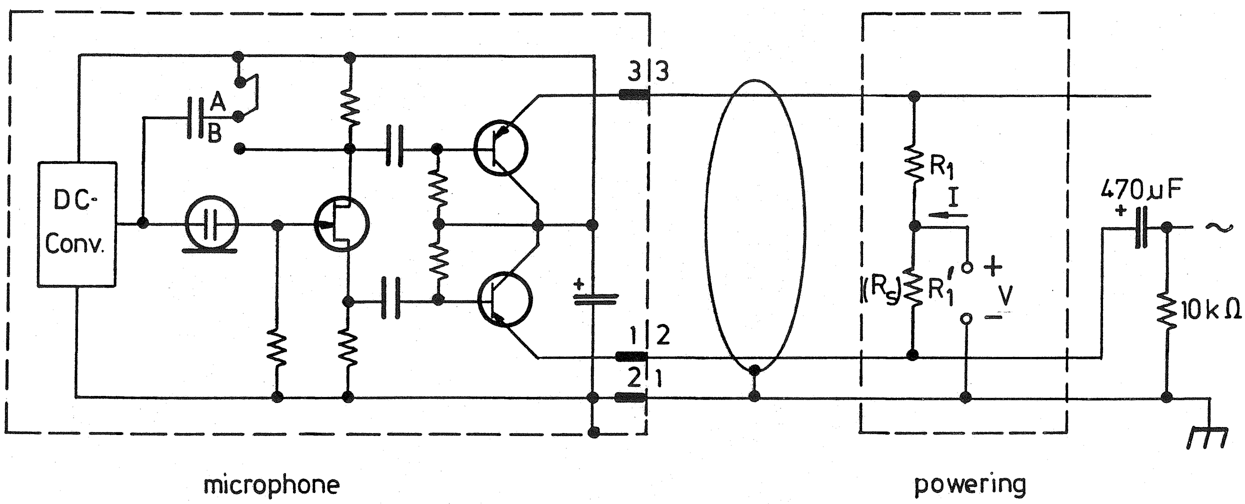


Figure 11. Microphone with output transformer (SCHOEPS CMT 50 circuit outline), showing connections to an unbalanced input

3.3.2.2 Phantom-powered microphones with transformerless class-A push-pull output circuitry (SCHOEPS Colette series) allow unbalanced connection through one modulation lead.

The powering may be applied as usual through both modulation leads ($R_1 = R_1'$) or through only one (R_S), which must be the one whose signal is used. This should preferably be the lead with positive signal phase. The DC powering voltage must furthermore be decoupled with a capacitor (figure 12).

The unused lead **must not be grounded,** either directly or through a capacitor.



Standard version:	Bridge "B" closed, gain = −3 dB	
Blue-dot version:	Bridge "A" closed, gain = +2 dB	(This version is the one shown above; it is recommended for this particular situation.)

For standard values of V, R, and I see Figure 3.

Special powering circuit using only one feed resistor R_S:

Amplifier type	CMC 3--	CMC 5--
V	+12 Volts	+48 Volts
R_S	560 Ohms	3.3 kOhms

Figure 12. SCHOEPS CMC 3-- and CMC 5-- (Circuit outline), with circuit arranged for unbalanced use

A general disadvantage of this method is that the push-pull output stage is not fully utilised, and that a signal of only half the original amplitude is offered. The various versions of the CMC amplifier series, furthermore, behave differently under these conditions, as follows:

3.3.2.2.1 Unbalanced use of the standard version of CMC 3-- and CMC 5-- amplifiers (Bridge "B" connected)

This mode of connection results in a 3 dB decrease in signal-to-noise ratio. Even so, the SCHOEPS Colette series microphones have better noise performance than is required under normal studio conditions. Nowadays, however, we are less tolerant of noise, and the above-mentioned method is to be recommended only for exceptional cases.

3.3.2.2.2 Unbalanced operation of CMC 3-- and CMC 5-- amplifiers with higher output level ("Blue dot" version, bridge "A" closed")

If bridge "A" in the amplifier is closed, it results in a better-suited microphone for unbalanced use. When the positive-phase modulation lead is used there will be practically no loss of signal-to-noise ratio.

These amplifiers will have 5 dB less headroom, since they show 5 dB greater sensitivity while their maximum output level remains unchanged (around 1 Volt). But the maximum sound pressure level for a SCHOEPS microphone is so high that there still will be no problem except in extreme cases, e.g. placement only a few centimeters away from an instrument.

3.3.2.2.3 Unbalanced operation of CMC 3-- and CMC 5-- amplifiers with built-in pad ("Red dot" version)

It is not recommended that this amplifier version be used for unbalanced connection without a transformer. The simplest alternative is to remove the pad and proceed as described in the appropriate foregoing section.

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