This technology was used on several consoles, such as the Soundcraft TS12, but it had a relatively short life as I came up with something better – the padless microphone preamplifier described later in this chapter.

Microphone and Line-Input Pads

Microphone pads, or attenuators, are used when the output is too high for the mixing console input to cope with; this typically happens when you put a microphone inside a kick-drum. Attenuators are also used when for reasons of economy it is desirable that the microphone input doubles up as a line input.

A typical arrangement is shown in Figure 13.4. The preamplifier has a typical gain range of +20 to +70 dB. There is an input XLR and phantom feed resistors R1, R2. C1 and C2 are DC-blocking capacitors to stop the phantom voltage from getting into the preamplifier; these should be as large as possible to preserve LF CMRR. Next comes a 20 dB balanced attenuator made up of R3–R6; note that the loading of the preamplifier input resistor R10 must be taken into account when designing the attenuator resistor values; one of the functions of this resistor is to prevent the preamplifier input from being open-circuited when the pad switch SW1 or the mic/line switch SW2 is between contacts. C3 and C4 are two further DC-blocking capacitors that prevent the input terminals of the preamplifier, which are not in general at 0 V, from causing clicks in the switching. C5, C6, and C7 increase EMC immunity and also keep the preamplifier from oscillating if the microphone input is left open-circuit at maximum gain. Such oscillation is not an indication that the preamplifier itself is unstable – it normally happens because the insert jacks, which carry the output signal from the preamplifier, are capacitatively crosstalking to the microphone input, forming a feedback loop. Ideally the microphone input should be open-circuit stable not only with the input gain at maximum, but also with full treble boost set up on the EQ section. This can be challenging to achieve, but it is possible. I have done it many times.

In line mode, the microphone gain is of course much too high, and the usual practice is to use a 30 dB attenuator on the line input, which allows a high input impedance to be set by R7, R9, while R8 provides a low source impedance to minimize preamplifier noise. This pad alters the gain range to −10 to +40 dB, which is actually too wide for a line input, and some consoles have another switch section in the mic/line switch, which reduces the gain range of the preamplifier so that the overall range is a more useful −10 to +20 dB. The larger and more expensive consoles usually have separate line-input stages, which avoid the compromises inherent in using the microphone input as a line input.

There is an important point to be made about the two attenuators. You will have noticed that the microphone attenuator uses four resistors and has its center connected to ground, whereas the line attenuator uses a more economical three resistors with no ground connection.

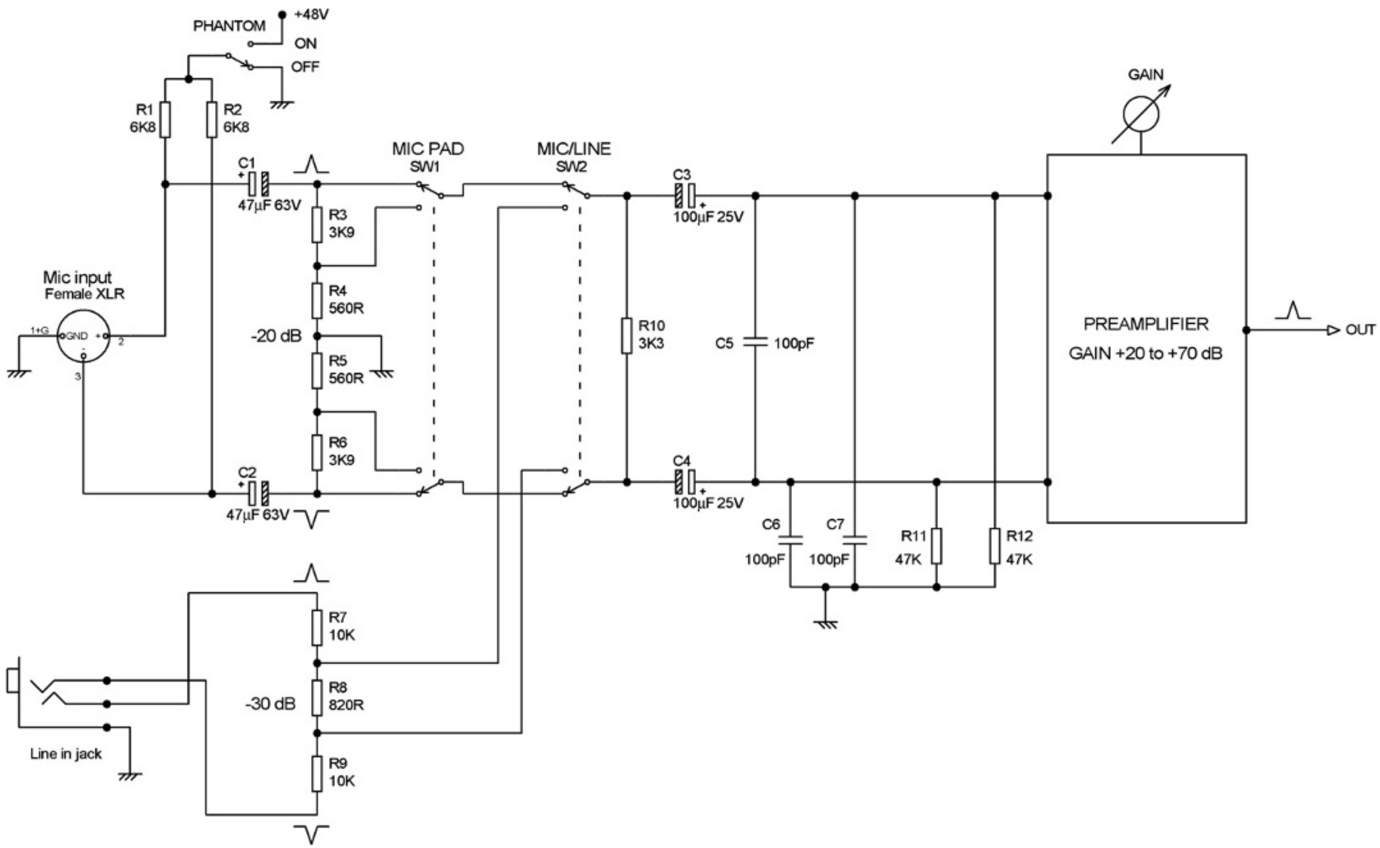

Figure 13.4: Mic and line attenuators at the input of a preamplifier

The disadvantage of the three-resistor version is that the wanted differential signal is attenuated, but the unwanted common-mode signal is not, and so the CMRR is much worsened. This does not happen with the four-resistor configuration because the ground connection means that both differential and common-mode signals are attenuated equally. There is no reason why the line attenuator here could not have been designed with four resistors – I just wanted to make the point.

The microphone amplifiers described have a high CMRR, and a problem with attenuators like this is that both types degrade the overall CMRR quite seriously because of their resistor tolerances, even if 1% components are used.

The Padless Microphone Preamplifier

The ideal microphone preamplifier would have a gain range of 70 dB or thereabouts on a single control, going down to unity gain without the inconvenience of a pad switch. It was mentioned in the previous section that resistive pads degrade the overall CMRR, and also the noise performance, as an inevitable consequence of following a 20 dB pad with an amplifier having 20 dB of gain. In addition, space on a channel front panel is always in short supply and losing a switch would be very welcome. I therefore invented the padless microphone preamplifier. Looking at the mixer market today (2009), the idea seems to have caught on.

The concept is based on the balanced-feedback mic amp described above, but now the total gain is spread over two stages to give a smooth 0–70 dB gain range with the rotation of a single knob.

The first stage shown in Figure 13.5 is based on the BFMA circuit in Figure 13.3, but with the feedback resistors reduced to 2k7 to reduce the gain range. The gain-control network R5, RV1, and C3 has also been halved in resistance to reduce Johnson noise, and the net result is a gain range of +1.5 to +49 dB; as before a reverse-log D-law pot is used. The lower feedback resistors mean that no servo is required to correct the DC conditions. Note that the greater amount of NFB means that under overload conditions it is possible for the common-mode range of the op-amp to be exceeded, leading to the well-known TL072 phase reversal and latch-up. This is prevented by R11, D3, and D4, which have no effect on linearity in normal operation.

The second stage of the padless mic amp is shown in Figure 13.6. This consists essentially of a variable-gain balanced input stage as described in Chapter 14, configured for a gain range of 0 to +20 dB. The gain pot is once again a reverse-log D-law pot and the combination of the gain laws of the two stages gives a very reasonable law over the almost 70 dB range, though there is still a little cramping at the high-gain end.

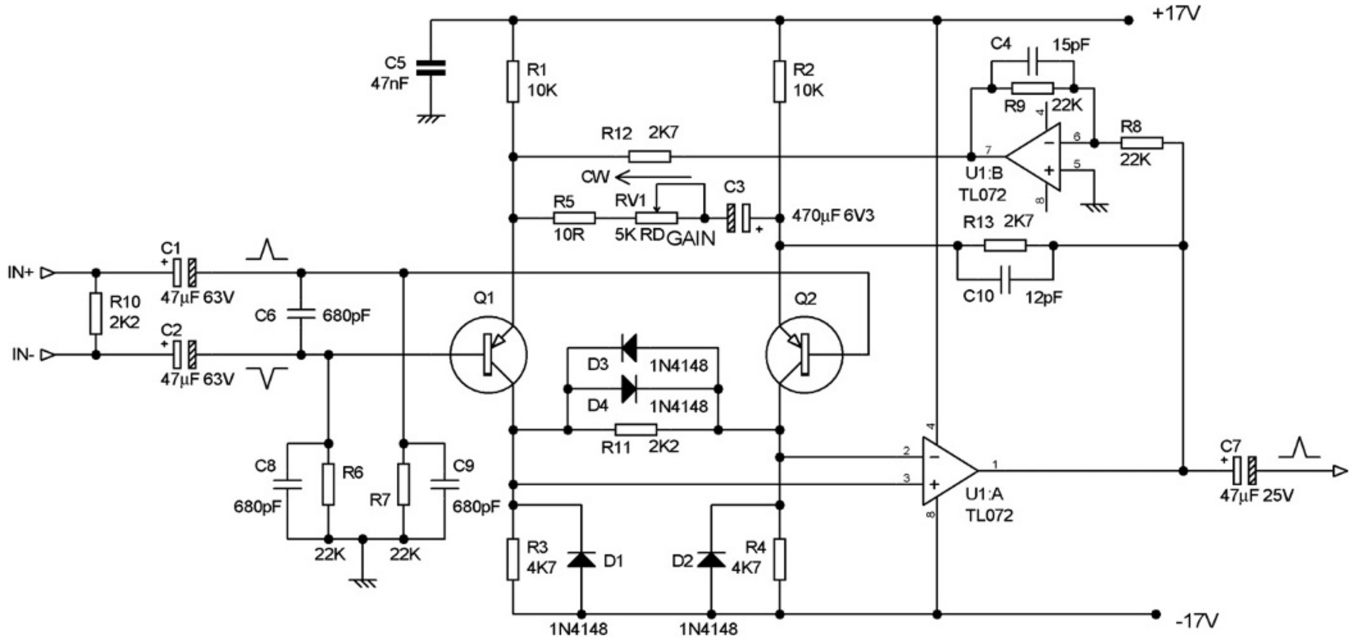

Figure 13.5: The padless balanced-feedback microphone preamp: mic input stage

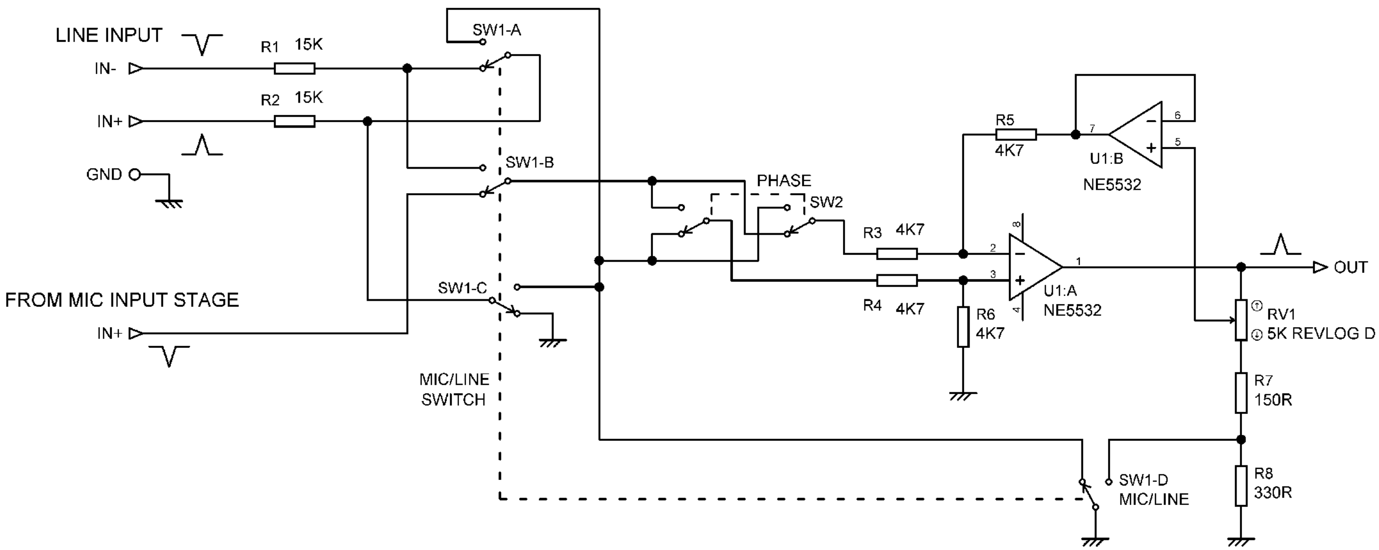

Figure 13.6: The padless balanced-feedback microphone preamp: mic/line switching and second stage

The second stage is also used as a line-input stage with a gain range of −10 to +20 dB. The mic/line switching used to do this may look rather complex but it does a bit more than simply change sources. In Figure 13.6 switch SW1 is shown in the 'mic' position, and the first stage reaches the inverting input of the second via SW1-B; the output of the mic amp is phase-inverted simply by swapping over its inputs. Line-input resistors R1, R2 give reduced gain for line input working, and in mic mode they are shorted together by SW1-A to prevent crosstalk from line to mic, which is an important issue when track normalling is incorporated (see Chapter 12). In several of my designs these resistors were placed on the input connector PCB rather than in the channel, to keep their hot ends away from other circuitry and further reduce line to mic crosstalk. SW1-C shorts the junction of R1, R2 to ground, further improving mic/line crosstalk if the line input is not balanced. SW1-D shorts the unused second-stage non-inverting input to ground.

In line mode R1, R2 are connected to the second stage via SW1-B and SW1-C. In mic mode, SW1-D shorts R8 to ground so that the gain range of the second stage is increased to the required 30 dB. SW2 is a phase-invert switch that simply swaps over the input connections to the second stage.

The padless mic amp gives both a good law gain control and lower noise at low gain settings. The noise performance versus gain for a typical example can be seen in Table 13.1; as described earlier, the EIN and noise figures worsen as the gain is turned down, due to the increased resistance of the gain control network. A noise figure of 30 dB may appear to be pretty dire, but the corresponding noise output is only −98 dBu, and this will soon be submerged in the noise from the following stages.

This effect can be reduced by reducing the impedance of the feedback and gain-control network, but this increases the power required to drive them, and because of the square root in the Johnson noise equation, a reduction by a factor of 10, which would need some serious

TABLE 13.1 Noise performance versus gain of padless mic amp

Gain (dB)	Noise out (dBu)	EIN (dBu)	Noise figure (dB)
1.4	−98.2	−99.6	30.0
6.6	−95.4	−102.0	27.6
15.4	−90.5	−105.9	23.7
31.7	−83.1	−114.8	14.8
44.1	−77.5	−121.6	8.0
51.8	−72.7	−124.5	5.1
60.6	−65.7	−126.3	3.3
69.3	−58.7	−128.0	1.6

electronics, would only give a 10 dB improvement, and that at the low gain end where it is least needed. Specialized outboard mic amps with low-resistance feedback networks driven by what are in effect small power amplifiers have been developed but do not seem to have caught on.

Another advantage of the padless approach is that one pair of DC-blocking capacitors suffices, rated at 63 V as in Figure 13.5, and this improves the CMRR at low frequencies. The padless microphone preamplifier concept was protected by patent number GB 2242089 in 1991, and was used extensively over many ranges of mixing console.

Capacitor Microphone Head Amplifiers

A capacitor capsule has an extremely high output impedance, equivalent to a very small capacitor of a few picofarads. It is in fact the highest impedance you are ever likely to encounter in the audio business, and certainly the highest I have ever had to deal with. Special circuit techniques are required to combine low noise and high impedance, working with a strictly limited amount of power. A while ago I designed the electronics for a new capacitor microphone by one of the well-known manufacturers, and the circuitry described here is a somewhat simplified version of that.

The first point is that the microphone capsule had an impedance of about 5 pF, so to get a −3 dB point of 10 Hz the total load impedance has to be no more than 3.2 GΩ (yes, that's 3200 MΩ). The capsule needs to be fed with a polarizing voltage through a resistor, and the head amplifier needs a biasing resistor. In this design both were 10 GΩ, which means that the input impedance of the amplifier itself had to be not less than 8.9 GΩ. Resistors with these astronomical values are exotic components that come in a glass encapsulation that must be manipulated with tweezers – one touch of a finger and the insulation properties of the glass are fatally compromised.

Figure 13.7 shows my capacitor mic head amp. R1 supplies the capsule polarizing voltage and R2 biases the first stage, a unity-gain JFET source-follower augmented by op-amp U1:A, which provides the gain for a high NFB factor to linearize Q1. The drain of Q1 is bootstrapped via C3 to prevent local feedback through the gate-drain capacitance of the JFET from reducing the input impedance. R3, R5, R6 set the DC conditions for Q1.

The second stage is a low-noise amplifier with gain of +4 dB, defined by the ratio of feedback resistor R17 to R15 and R16. Like the first stage, it is a hybrid design that combines the low noise of low-R_b transistor Q2 with the open-loop gain and load-driving capability of an op-amp.

The stage also acts as a unity-gain follower, making up a second-order Butterworth Sallen-and-Key high-pass filter when C6, C7 or C8, C9 are switched in; the resistive elements are R10 and R14.