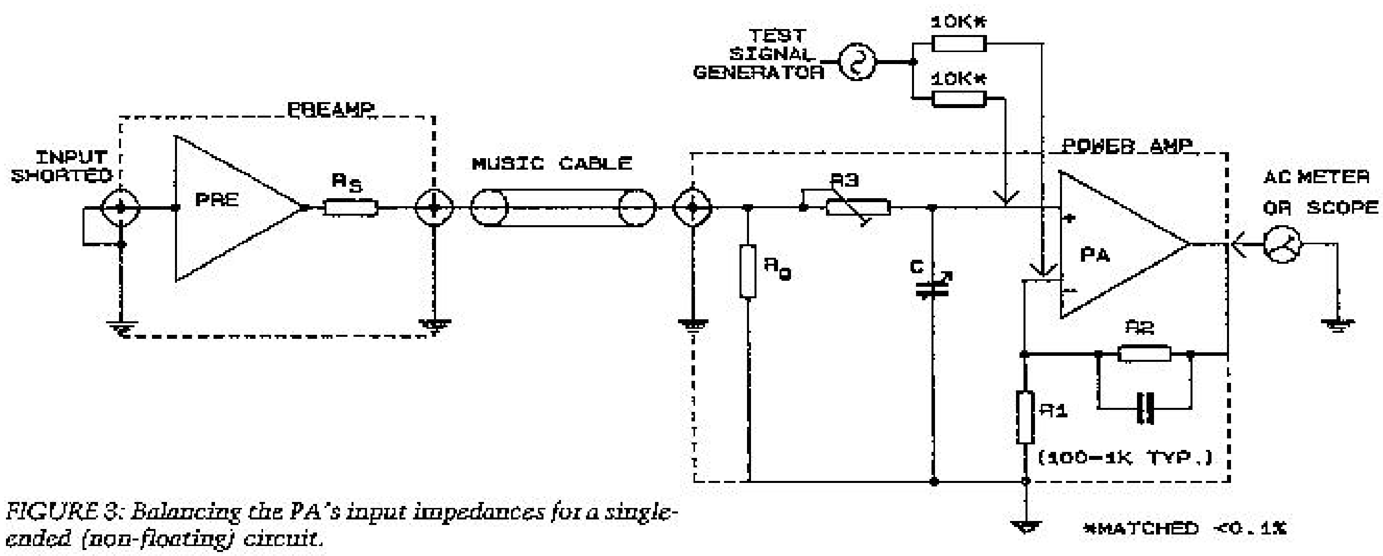

FIGURE 3: Balancing the PA's input impedances for a single-ended (non-floating) circuit.

tain common-mode signals within themselves (*Fig. 1*).

Because a common-mode signal is the average level of the signal, it is imperative to balance the differential input stage. Each side of the differential pair or transistor must be symmetrical and match. Matching the component characteristics of one side of the differential stage to those corresponding elements on the opposite side improves common-mode rejection and decreases thermal drifts. This includes the source impedances seen by each side as well as transistor/tube mismatching, inequality of load impedances, and unequal voltages and currents. They *must* all be balanced.

Standard Rejection

Just because a circuit accepts a floating input signal does not mean it is a balanced circuit. For example, unequal input impedances from each input to common contribute to errors. *Figure 2* shows CMR improvements of a circuit topology similar to Borbely's line-level amplifiers (Hafler XL280, data circa 1985.) Borbely's (and others') *TAA* circuits are highly unbalanced in their input-stage impedances.

Nevertheless, balancing the impedance (AC) easily improves its common-mode rejection seen by each differential input-stage transistor. This procedure is not as simple as making the circuit resistor values equal at each of the inputs. The process must also include source-output impedance driving the amplifier, which usually varies with frequency.

For now, this common-mode rejection improvement is not possible on a large scale because standard-source output impedance does not exist. If we could settle on a standard—such as 50Ω or 100Ω—all power amplifiers would have the ability to offer their best common-mode rejection capability.

Indulgence

Figure 3 depicts how I tune a single-ended (non-floating signal) power amplifier for better CMR (Common Mode Rejection). With the proper test equipment and experience, you can learn to improve the performance and sound of your audio equipment from this example. The object is to match the impedances recognized by each transistor's differential amplifier input. Generally, the side receiving the feedback signal registers the gain-setting resistor's approximate value, typically 100Ω–1kΩ. Now, if your source, or preamplifier, impedance is lower than this, we can add resistance to the source input (+) side of the power amplifier's differential stage to balance the two impedances (presented to the differential input stage). If your source impedance is slightly higher, you may be able to reduce the preamp-output series resistor to a low enough value.

I applied the same signal to both inputs and monitored the output of the power amplifier. To do this properly, you must connect your preamp or audio equipment (turned on but no music) to your power amplifier with the interconnect cable you normally use for listening. The inputs (+) and (−) are connected by using a pair of 10K ¼W resistors matched to within 0.1% directly to the FET gates of the power-amplifier differential pair. When both input impedances are equal, common-mode output from the power amplifier will be minimal. I inserted a small trimmer potentiometer (500Ω–1kΩ) on the power amplifier PCB in series with the input and a trimmer capacitor to ground in order to make the adjustments. I adjusted the series resistance at 1kHz and the added capacitance for minimum output at 20kHz. This method custom tunes the *system* for best performance. If you change the equipment or cable, you must make the adjustment again.

Further improvements in CMR place circuit-topology refinements is beyond the reach of non-designers. Before we indulge in perhaps self-defeating, overly complex circuitry, let us at least get the circuits' input and output impedances truly balanced. It makes a difference.

If you find the results of balancing the differential stage convincing, you will agree that we are missing out on a very important area of testing and design. Designers can develop better balanced differential circuits from input to output if they consider the benefits beyond noise concerns. Better differential circuits will lower distortion due to the reduction in common to differential-mode conversion.

If analog is to continue to provide the best possible performance, standard input and output impedances will go a long way in helping applications engineers and designers accomplish the task and take a "mysterious" variable—equipment interaction—out of the subjective equation. □