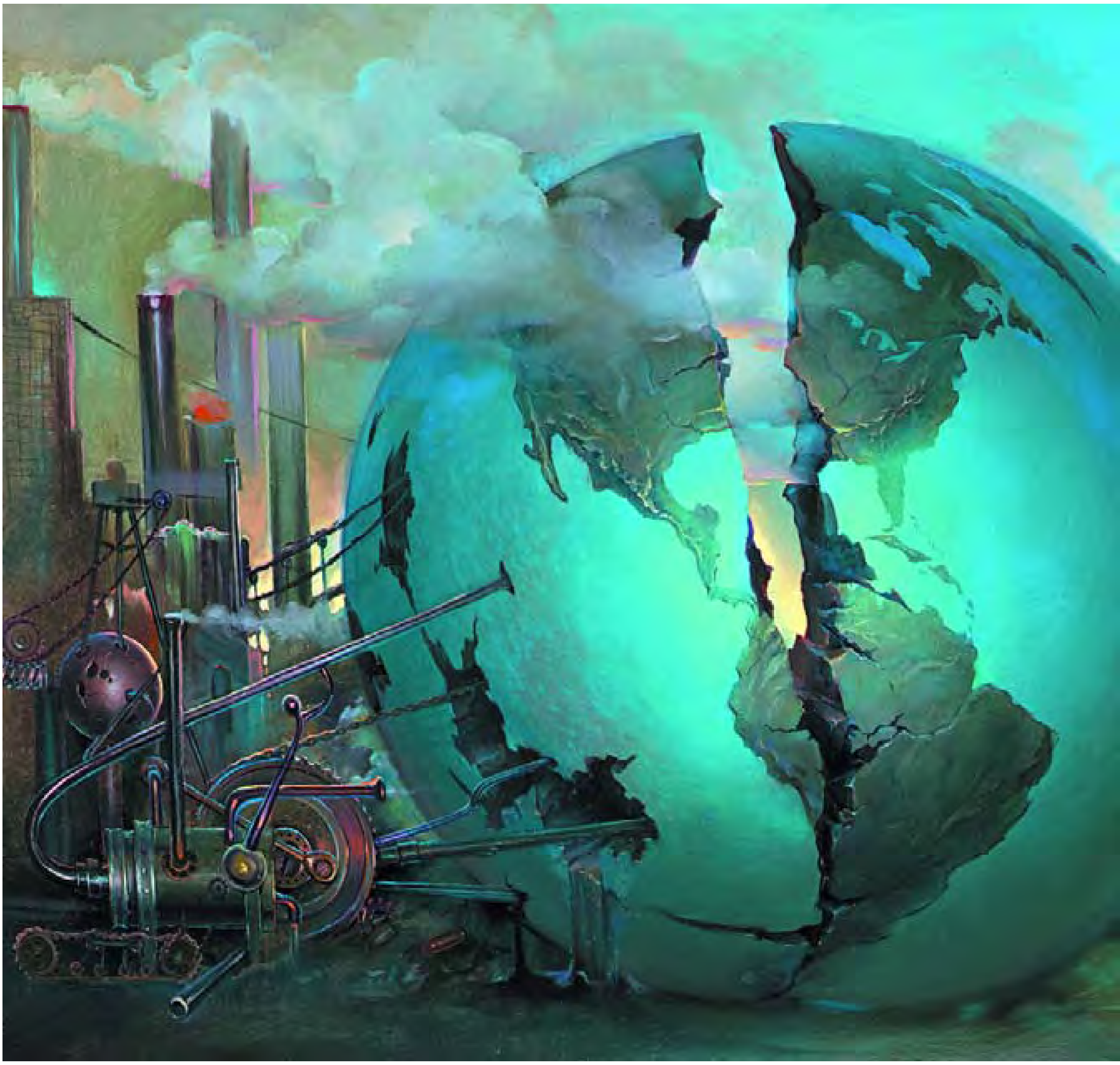
Star-point Grou



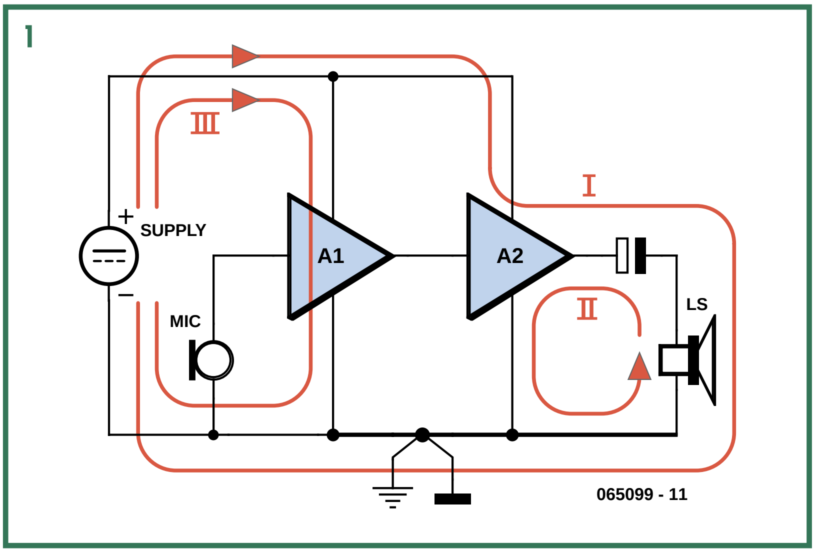
Karel Walraven

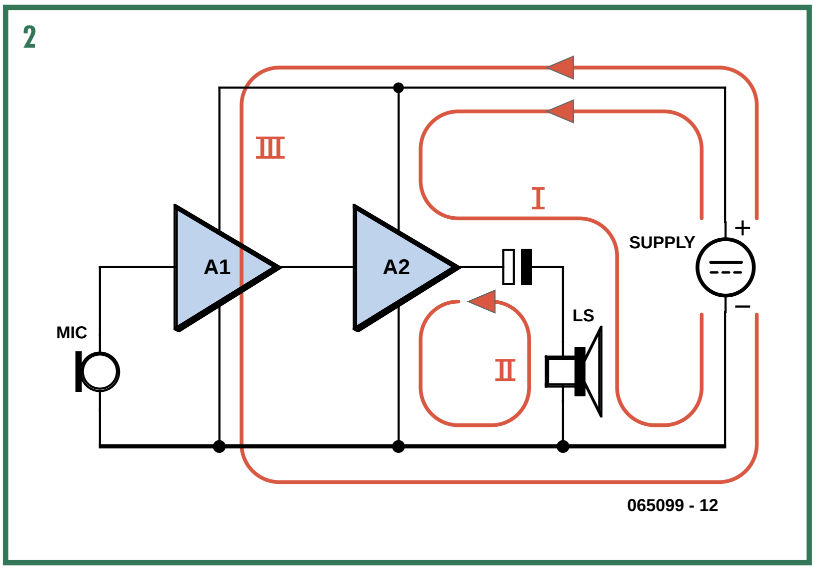
It is assumed that every electronics engineer knows what is meant by ground, earth and safety earth. Nevertheless, these terms still belong to the great mysteries in the land of electronics. Here is an attempt to lift the veil a little...

unds

Forcing current in the right direction


'Split World' illustration reproduced courtesy of John Pitre (www.johnpitre.com)

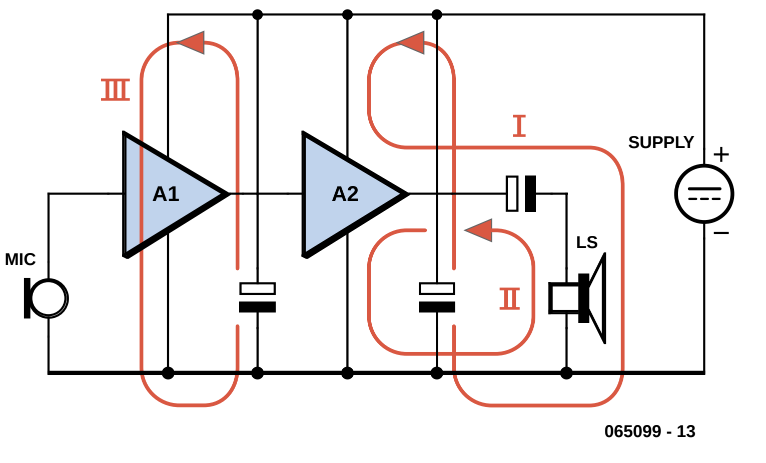




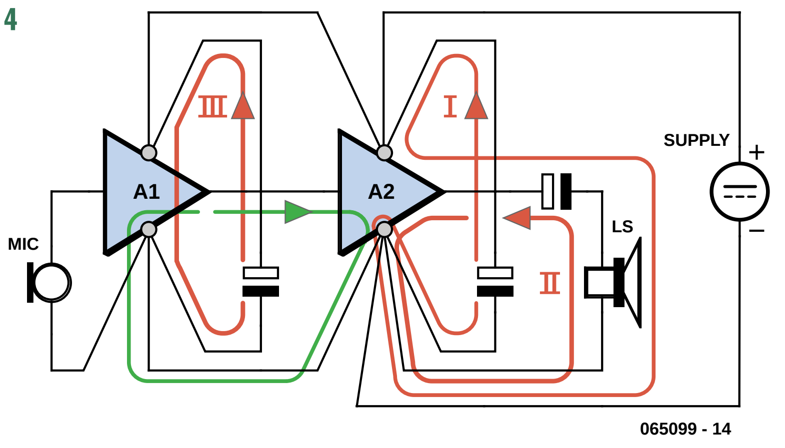
It will not have escaped you that the human race, normally speaking, stands firmly with both feet on the ground. Even those who tend to be on an esoteric plane speak constantly about 'earthing'. The worst thing that could happen to you is that you're not earthed, because then the brakes are gone and you're unprotected and subject to the whims of the surrounding elements.

Fortunately it is not quite that bad in practice. You tend to survive a visit to the Eiffel Tower and even flying high above the earth to distant places appears to lead to very few problems. We can conclude from this that it is not that important where you are, as long as your environment is stable. The same is true in the world of electronics when we're talking about the term ground. With the term ground we usually mean some more or less arbitrary point in a circuit. To keep this a little workable, we usually take this point as the negative supply voltage or a point halfway between the positive and negative supply voltage. In our thinking we assume for simplicity that this

3



4



ground point provides us with certainty, is stable and is the same everywhere. If only it were true…

In **Figure 1** is drawn a very simple example that can help us to understand the phenomena that occur. There is a signal source (micr), a pre-amplifier A1, a power amplifier A2 with a loudspeaker and finally a power supply. A ground symbol is drawn is well, the short, thick, horizontal bar. Advertently or inadvertently we assume that, *solely by drawing this symbol*, all the parts connected to it are suddenly and in a mysterious way at the same potential, irrespective of changes in the surrounding universe. The reality is different. In the first instance it is not meaningful to talk about potentials, there are only continuously changing voltages and currents. They are dynamic events. So even in the ground conductor there are differences and the only thing we can do is to make these differences as small as possible by cleverly designing both the circuit itself and the printed circuit board. It gets even worse when we add another symbol: earth. Now the circuit has got to be stable! We have now, after all, connected it to everything around us! That's done by using a conducting rod that we stick in the 'earth'. Too bad, but this doesn't help us much either. Flowers do quite well in this earth, but our electronics is really not going to be more stable because of this.

We have to be convinced that placing the ground symbol doesn't really change anything and that it is there only to clarify and make it easier to think about the circuit. Noise sources can (read: will) develop across signal conductors; the ground conductor is made from exactly the same copper trace and the same noise will also occur in it. Let go of the idea that a circuit needs an 'earth' or a 'ground'. There are many battery powered devices that are completely 'floating' and nevertheless work quite well.

We are now complete free from 'earth', we float. All interconnections in **Figure 1** are cursed with a little resistance, a certain amount of self-inductance and also have some mutual capacitance. To put it briefly, they are not ideal connections, but connections as they are in the real world.

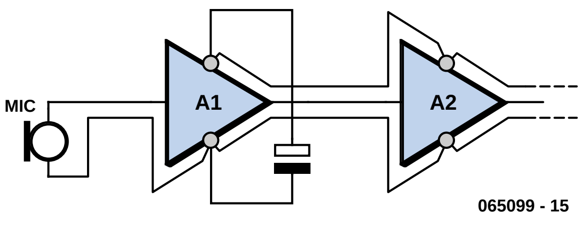
The variable current (music) that runs through the loudspeaker will generate variable voltages across the connections through which this current also flows. So the power supply voltage to A1 and A2 is influenced and because the current also runs through ground, the ground at the minus terminal of the power supply will not be equal to the ground at the loudspeaker terminal. The resulting problems are obvious at the microphone input. Current flows through the ground connection, which results in voltage changes and these are added to the microphone signal and amplified.

It is the *current* that causes the problem.

Make a copy of the schematic and draw the significant currents on it. We will now draw the schematic again, but now we will try to isolate the currents as much as is possible. Just by moving the position of the connections to the power supply we already make a significant improvement, the microphone is now no longer influenced by the loudspeaker current (**Figure 2**). You can now also appreciate why the decoupling capacitor is important. This causes the variable currents to remain local and do not wander all over the circuit (**Figure 3**). We ultimately end up with a schematic in which the power supplies have star-shaped connections, because with this topology the mutual influence is minimised (**Figure 4**). For example, there is no longer an interfering power supply current in the signal path between the two opamps (drawn in green). Once you've gone through this exercise, you're actually done. The layout of the PCB is easy based on the re-drawn schematic. Moreover, make all loops in the layout as small as is possible (**Figure 5**).

As we have already made clear in the 'PCB design basics' in the February 2005 issue, every PCB is a com-

5

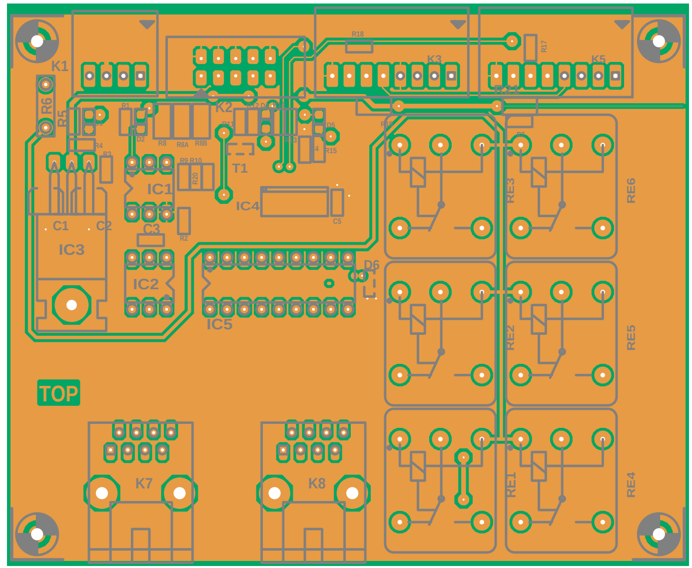


promise. When you have to choose, for example, whether to favour a signal conductor or another conductor then it is obvious that the trace that carries the signal has priority. Maybe this is labouring the point a bit: the return path is also a signal path, always look for signal current loops. In our example the signal return path is 'coincidentally' ground. Many designers deliberately design it this way because it is easy to think about and straightforward to make measurements. It is always a good idea for a double-sided PCB to make one side completely ground. But even then you cannot let go of the idea of a star-point ground and if necessary use separated ground planes (**Figure 6**). However, don't exaggerate these things, separated ground planes can also act as antennas and the cure is then worse than the illness.

Safety earth and screening

With Class I devices, the circuit is connected to safety earth. This ensures that no dangerously high voltages can appear on parts of the circuit that can be touched. Always be very careful with this, because sizeable currents can flow. This also applies to the screens of cables. Design your PCB in such a way that these types of current that you rather not have around, do not wander all over the PCB. Therefore: a separated earth plane for connections to safety earth and screens and another ground plane for the circuit. Obviously these two planes have to be electrically connected, but do this at only one point so that there is no loop for current to flow. Figure 6 shows an example. All the connectors are together on an earth plane, the star-point is at the regulator IC and from there one plane for the µP and one plane for the power stage (the relay).

6



(065099-1)