

amount during the three periods of acceleration, while Peter ages regularly by 30 years during the complete process: hence, when they meet again, Peter's age is 30 years and Paul's three days. On the other hand, if Peter is the traveller he ages by 1.5 days during each of his outward and return journeys, and by almost 30 years during the change from recession to approach with respect to Paul, while the stationary Paul ages by 15 years during Peter's outward journey, changes during Peter's reversal to a state nearly 15 years before birth, and then ages by 15 years during Peter's return, somehow getting born shortly before Peter arrives. Consequently, when they meet, Peter's age is 30 years and Paul's three days — exactly as in the former case.

We can hardly suppose that Einstein, Born and the others believed that these processes were both actual occurrences, the one entitled to claim reality depending on our preference in choosing to whom to assign the motion, nor did they. What they supposed was that the only observable events in the whole process were the separation of Peter and Paul at the beginning and their reunion at the end. Everything that happened in between was regarded as being beyond possibility of observation and therefore demanding compatibility only with theory, not with experience, with which it had nothing to do. This is obviously so important that it is necessary to confirm it by quoting Einstein's own words (in translation), all that needs explanation being that the clock U_1 is Peter and U_2 Paul and that "the right and left hand columns" give the descriptions of the process, as I have described them, when Peter and Paul, respectively, are regarded as moving. Einstein writes³:

"You must bear in mind that exactly the same process is described in the right and in the left hand columns, but the description on the left refers to the coordinate system K while that on the right refers to K'. According to both descriptions, at the end of the process the clock U_2 is retarded by a definite amount compared with U_1 . With reference to K' this is explained as follows: it is true that during the stages 2 and 4, the clock U_1 , moving with velocity v , works more slowly than U_2 , which is at rest. But this retardation is over-compensated by the quicker working of U_1 during stage 3. For, according to the general theory of relativity, the clock works the faster the higher the gravitational potential at the place where it is situated, and during stage 3 U_1 is indeed situated in a region of higher gravitational potential than U_2 . Calculation shows that the consequent advancement amounts to exactly twice as much as the retardation during stages 2 and 4. This completely clears up the paradox."

What Einstein means here by "the same process" is, of course, everything that is observable, while "the description", which differs in the two cases, is wholly a mental construction. The first is unique, for it must be the one thing

that would actually occur; the last owes allegiance only to theory, not observation, and can vary within the limits allowed by the theory.

But it is clear, beyond possibility of question, that Einstein's "descriptions" relate to what is observable, and cannot therefore both be permissible; and furthermore, as the credentials of both are exactly the same, it is impossible to decide which must be rejected. Paul could be accompanied by a nurse, of such an age as to become 30 years younger without losing her power of intelligent observation, and she would report on return whether it was a baby or a teenage boy who arrived at the planet, and whether or not a baby was born during the return journey, even if she were unable to confirm the antenatal age of the being whom the planet left. The question I asked Dr Wilkie was, in effect, whether what the nurse would observe would admit of both of Einstein's "descriptions", or whether a

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theory that required it to do so must be abandoned. I am not surprised at his reluctance to commit himself to a choice; nevertheless, it is imperative that scientists shall make a choice if the ethical demands of science are not to be jettisoned.

What is the net result of all this? As I have said, it throws no light at all on what would happen if the experiment were made, for it is an analysis, not of a physical process that has never occurred, but of the requirements of a theory that purports to accord with physical processes, and I think it shows beyond doubt that the special relativity theory at least must be wrong. If the motion can be ascribed equally rightly to either twin, it cannot make them age at different rates; if it makes them age at different rates, there must be an absolute standard of rest to provide a criterion for distinguishing the faster from the slower developer. The special relativity theory requires different rates of ageing to result from motion which belongs no more to one twin than to the other: that is impossible.

It is impossible to exaggerate the importance of this result, for this theory is, by common consent, "taken for granted" in Max Born's words, in all modern atomic research, and it determines the course of practically all current developments in physical science, theoretical and experimental, whether concerned with the laboratory or with the universe. To continue to use the theory without discrimination, therefore, is not only to follow a false trail in the investigation of nature, but also to

risk physical disaster on the unforeseeable scale, modern atomic experiments being what they are. It should therefore be a point of honour with those on whose authority atomic research is now being conducted to acknowledge at once the untenability of the theory, and to take without delay the necessary steps to discover where the theory falls.

That does not necessarily mean complete abandoning of its use, but it does demand the determination of the limits of its usefulness. It has already proved its effectiveness in many respects, and this has been mistaken by physicists for evidence of its truth. What the many successes of the Lorentz transformation equations have shown is that those equations are an effectual corrective of the imperfect classical electromagnetic equations within a limited range of experience. But it is now clear that the interpretation of those equations as constituting a basis for a new kinematics, displacing that of Galileo and Newton, which is the essence of the special relativity theory, leads inevitably to impossibilities and therefore cannot be true. Either there is an absolute standard of rest — call it the ether as with Maxwell, or the universe as with Mach, or absolute space as with Newton, or what you will — or else all motion, including that with the speed of light, is relative, as with Ritz. It remains to be determined, by a valid experimental determination of the true relation of the velocity of light to that of its source, which of these alternatives is the true one. In the meantime, the fiction of "space-time" as an objective element of nature, and the associated pseudo-concepts such as "time-dilation", that violate "saving common sense", should be discharged from physics and philosophy, and the fact realised that mathematical consistency, though a necessary condition, is not a sufficient one for the truth of a physical theory. Only thus can the scandal of more than half a century of confusion about the meaning of our own creations be ended.

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Audio gain controls

A survey of the methods used to achieve acceptable control of gain in audio amplifiers.

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The design of gain controls is by no means as simple as it might appear. Peter Baxandall examines the difficulties in design and comments on many circuits which have appeared over the years, from very simple types in which compromises must be accepted, to those used in high-performance equipment.

An ideal audio amplifier with variable gain would have the following characteristics:

- (i) noise output voltage = (source Johnson noise voltage) × (gain)
- (ii) ability to deliver its full output voltage even at very low gain settings, which may be less than unity. The amplifier is therefore capable of handling very large input voltages at the lowest gain settings.

The simplest way to achieve (i) is that shown in Fig. 1(a), but this simple tech-

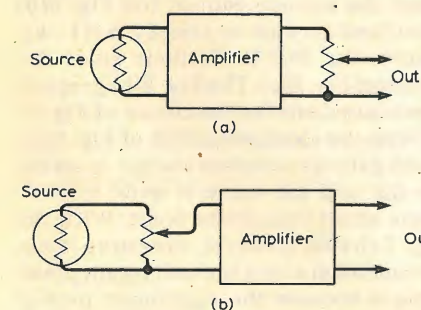


Fig. 1. Two small gain controls which do not fulfil both main requirements. Circuit (a) gives low noise, but will overload at low gain settings, while (b) introduces additional noise.

nique obviously fails lamentably with regard to (ii), for the maximum input voltage that can be handled without overloading is the same at all settings. The arrangement of Fig. 1(b), on the other hand, achieves (ii) perfectly, but fails with regard to (i).

By using sufficiently subtle gain-control systems, it is possible to satisfy (i) and (ii) concurrently and almost perfectly, but the simple and widely used arrangement shown in Fig. 2 provides a compromise solution which is very satisfactory for many practical purposes.

An ideal amplifier would give a variation of output noise voltage with

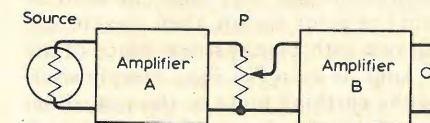


Fig. 2. This arrangement combines circuits of Fig. 1(a) and (b) to give compromise performance.

gain setting as shown by the full-line graph in Fig. 3, whereas the Fig. 2 scheme gives a characteristic as depicted by the broken line. Below a certain setting of P, the noise level from amplifier A at the output of P becomes less than the noise level of amplifier B referred to its input, so that the noise of amplifier B becomes the dominant contribution, establishing the level of the broken-line "plateau".

Now there is obviously no practical advantage in achieving an output noise level which is a long way below audibility at very low gain settings, so that a characteristic of the broken-line type is normally perfectly satisfactory, provided the level of the horizontal plateau is low enough. For a given overall maximum gain requirement, the product of the voltage gains of amplifiers A and B in Fig. 2 is fixed, but there is a choice with regard to the apportionment of this gain between the two amplifiers. The higher the gain of A is made, the lower is the position of the Fig. 3 plateau, but there is the disadvantage that the maximum signal input that can be handled without overloading amplifier A is reduced.

In domestic audio control units, the

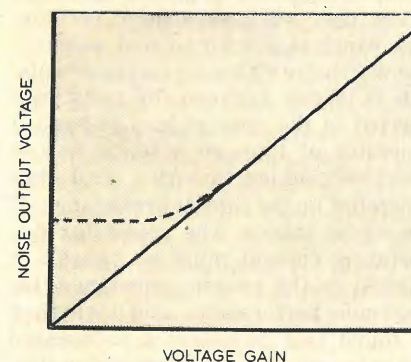


Fig. 3. Dotted line shows gain variation given by circuit of Fig. 2, where residual noise from amplifier B is predominant at low gain settings.

Fig. 2 arrangement is usually used. A suitable choice for the gain of amplifier B is normally such that full output level is delivered to the following power amplifier for an output level from the pot. slider of about 100mV r.m.s. If the wideband noise of amplifier B, with P set to zero, is equivalent to a noise input voltage to B of 0.5μV rms, which is fairly readily achievable, the zero-volume-setting noise output from B will then be 106dB below the full signal output level. (It may be added, however, that if the gain of B is made high enough to cope with the least sensitive of power amplifiers, which may require an input level of several volts, then the signal level at the pot. slider for full power output when used with a very-high-sensitivity power amplifier, will be much less than 100mV rms, and a figure much less than the 106dB mentioned above will then apply. Thus, for versatile use, it is desirable to provide a preset gain adjustment within amplifier B, or in the form of a simple passive attenuator after this amplifier.)

A closer approximation to concurrently satisfying conditions (i) and (ii) at the beginning of the article may be obtained, on the same principle as in Fig. 2, by employing three amplifiers with ganged gain-control pots. between them, but in general it is much better, instead, to employ schemes in which variable negative feedback provides much of the gain variation.

Variable-feedback gain control offers advantages both with regard to achievable performance (noise and signal-handling) and often with regard to economy of circuit design. Variable feedback alone cannot normally reduce the gain to zero; for 100% voltage feedback reduces the gain to unity rather than zero. Thus, it is usual to combine feedback variation with passive gain control, sometimes using a ganged pot. and sometimes using the parts of the track either side of the slider, in an ordinary single pot., to perform these functions. There are many possible schemes, of which some have been known for thirty years or more.

One of the simplest schemes is that shown in Fig. 4. The pot. resistance can be made quite low, e.g. 1kΩ, since it is driven by the op. amp., not the signal source. This results in a good noise performance at all settings. Disadvantages of the circuit are: