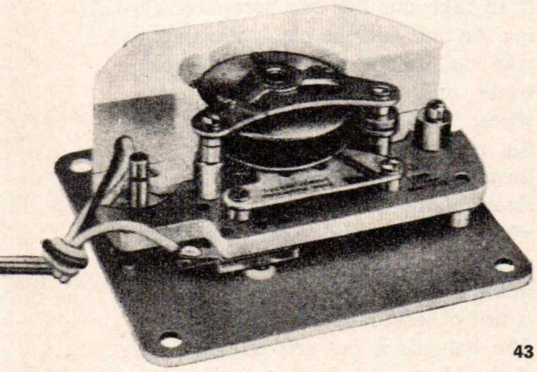
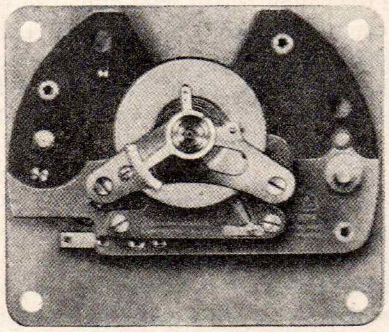
Electrical and Electronic Timepieces and Their Maintenance

by Lothar M. Loske

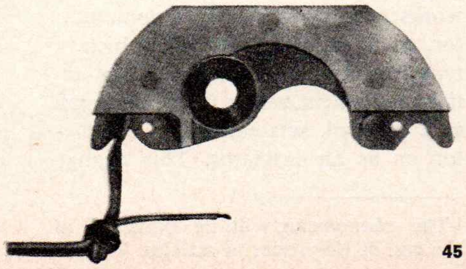
(See «Swiss Watch & Jewelry Journal» Nos. 5-6/1965 and 4/1966)



43



44



45

ESA Movement No. 9100

This Ebauches S.A. movement (Fig. **43**—see also Fig. **7b**) marks progress in the realization of clock movements based on new ideas. As far as the outward appearance goes, it cannot be distinguished from the Ebauches movement ESA 9000/9001 which was recently described; the size and mechanical parts are identical. The application is also the same; it is intended for a small electric alarm clock.

The electronic impulse arrangements for the balance are the result of technical development. To justify describing the impulse as electronic, the mechanical contacts for completing the electrical circuit have been eliminated. The balance receives impulse as a result of a magnetic field and the attraction of a solenoid as before, but the closing and opening of the circuit is achieved electronically.

This apparently mysterious maintenance of the balance movement ought to be accepted by the watchmaker quite easily. The most delicate part of all electric watch and clock movements, the delicate springs and contacts, are eliminated. Repair is facilitated; the electronic components do not complicate the matter. Here, as in ESA calibre 9000, the complete electronic unit can be separated from the plate by removing two screws. All the electronic and magnetic components are to be found in a white container made of synthetic material. This unit must be lifted off sideways, away from the plane of the balance; otherwise, there is a risk of bending and damaging the particularly delicate coil against the disks of the balance.

The contact spring block with the thin blades and contact pins (see Fig. **35**) does not exist any more. The classical form of the balance has also disappeared; the rim has been replaced by two thin disks. Several small holes and milled recesses show that the poise of the balance has been carefully checked. This is also born out by the presence of a poised roller. The impulse pin is neither triangular

Fig. 43. Transistorized movement ESA 9100, battery driven. 7 jewels with alarm release device. The electronic circuit contains one transistor.

Fig. 44. Movement ESA 9100 shown without the electronic unit. The mechanical unit comprises the plate, wheel train, balance cock, balance spring stud, alarm release device, and the balance and spring. The latter comprises two thin disks connected to each other, but separated by a normal roller and a balance spring. Two permanent magnets are mounted on the outer faces of the disks; they serve to actuate the transistor, and thus the coil giving impulse to maintain the balance; the other small masses at 180° maintain the balance in equilibrium.

Fig. 45. Electronic unit of movement ESA 9100 with double coil. In the event of any defect it can be replaced entirely.

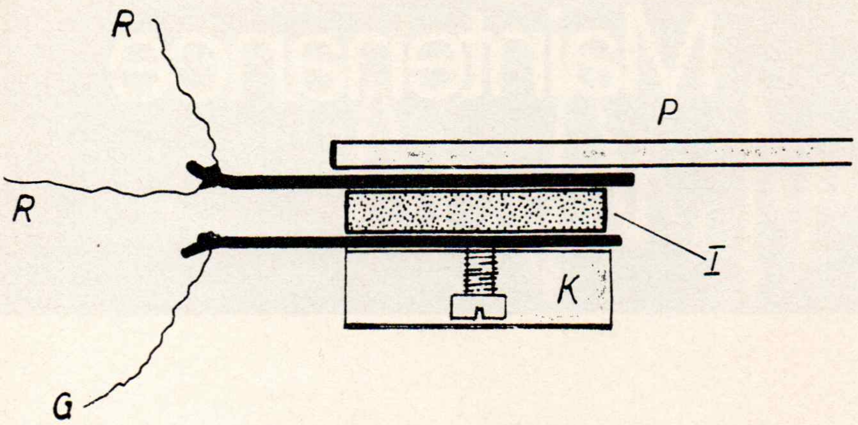


Fig. 46. Unit and connections in calibre ESA 9100.
P = plate;
I = insulating spacer;
K = plexiglas block with screw;
R = red wire;
G = yellow wire.
The terminal of the yellow wire must not have any metallic connection with the terminal of the red wire, or with the plate.

nor semicircular; it is of such a form that "elliptical" would be a better description. Two permanent magnets, in the form of two cylindrical masses of dark colour, lie between the two disks comprising the balance. Their magnetic attraction is extremely powerful, so that the cock should not be lifted off without non-magnetic tweezers. The balance spring may be distorted, or the pivots bent, if one does not allow for the attraction of the magnets **(Fig. 44)**.

For repair, follow the advice given under the heading **repair procedure** for calibre ETA 2420/2421. With the exception of the electronic unit **(Fig. 45)**, all the parts, including the balance with its permanent magnets, can be cleaned in a machine. The cleaning liquid must be very clean, and not contain steel particles or burrs. Magnetic particles of this sort will remain stuck to the magnets and can only be removed by pegwood with difficulty. Further cleaning will have no more success, even with a higher speed of basket rotation.

To part the electronic unit from the cable connecting it with the mechanical unit of the alarm release, remove the screw of the corresponding unit **(Fig. 46)**. One may then separate the wires from their terminals to allow the electronic unit to be put on one side immediately. Unfortunately, the screw which retains the terminal block is only accessible from the dial side, so that the first operation cannot be the separation of the electronic unit. Comparison of Figures **46** and **40** (calibre ESA 9000/9001) shows little difference between the circuits. Basically, nothing is changed in the circuit except that the upper connection is soldered to two red wires. The second wire is necessary because the plastic container of the electronic unit is not a conductor, and thus will not be connected to the terminal of the cell which is earthed (to the plate) to provide connection to the impulse coil.

Checking the electronic switching device.

Under **New professional studies** we stated that the repairer has no need to study electronics. The possibility of intervention by the repairer is exhausted from the moment that he realizes that the effect he is looking for is solely dependent upon the electronic unit. In other words if the electronic unit does not function properly, it must be replaced, and no attempt made to deal with the transistor or the coil.

In calibre ESA 9100 it is understood that the electronic unit produces, according to the rythmic motion of the balance disks, a magnetic field capable of maintaining the oscillatory movement of the balance. Checking the existence of the magnetic field is not as simple as in calibre ESA 9000/9001 (see Fig. **37**) because now the circuit is not completed by an ordinary contact; checking the behaviour of the electric components is not much more difficult, it is only carried out in a different way. Here, the charm compass is useless, because it is affected by the magnet carried by the balance disks, even if the electronic unit is defective.

There is no reason to start general repair work before checking the electronic unit. The most judicious way is to take out the two screws retaining the unit and the plate, and then to take out, to the side, the whole electronic unit without disconnecting the wires; then take off the cock and the balance, remove the pallets, and then replace the balance. When the electronic unit is replaced, connect the **white wire to the negative terminal** and the **red wire to the positive terminal** of a 1.5 volt cell. If this polarity is not observed nothing will happen.

The balance is not self-starting, even if the electronic circuitry is in order; it is necessary to give it a first impulse, which need not be very strong. The explanation of the expression "to excite the system" is explained schematically in Figure **47** without entering into the explanation of the physical phenomena taking place within the electronic components.[1]

As in the electric calibre with mechanical contacts there is a coil whose magnetic field—when a current flows through it—attracts a mass solid with the balance. The mechanical contact which, in all the electric calibres (and in electric wrist-watches) is actuated by the balance staff fundamentally, is eliminated in the electronic calibre. That which closes the circuit, which works as a contact, or as a commutator, is a transistor, within which a type of inversion takes place. The active component, which may be as small as a pinhead, acts either as a conductor or as an insulator. This change

[1] The phenomena will be explained at the end of this series of articles.

can be produced by the influence of a very weak current passing through the transistor. This current does not come from the battery, but as a result of the motion of the balance.

What has become of the venerable classical balance? Earlier this was, with the balance spring, an extremely sensitive controlling organ. Later, with an electrical source of energy it actuated the wheel train, and finally it has become itself a producer of energy controlling the rythm of the impulses.

To become a switching device, the transistor needs a current; in this case, an induced current is produced when the magnetic field of the permanent magnets carried by the balance crosses the coil of the electronic unit from which one may see, from underneath, four leads and four soldered connections. A coil has a wire with two ends; but in this case there are four ends, this is because there are two coils within the same space. The windings, and their terminations, are so fine and delicate that it is not advisable to touch them, even when they appear dirty, it is better to leave anything which cannot be dislodged by means of a blower.

During the motion of the magnets carried by the balance, one of the coils produces the induced current to actuate the transistor. The second coil is included in the supply circuit, and as a result of the magnetic field produced, exerts an attraction on the balance which maintains its oscillation. The induced current is interrupted in the same cycle, when the transistor becomes an insulator. An interruption of the current flowing from the cell to the impulse coil is produced so that

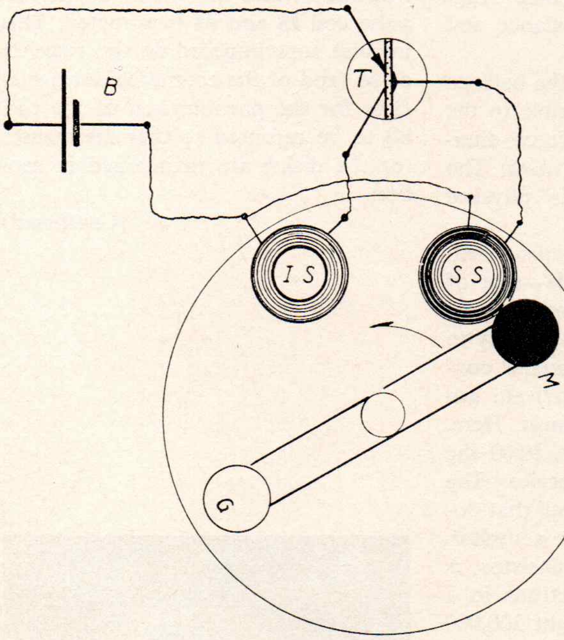


Fig. 47. Schematic circuit of the excitation of a magnetic coil using a transistor. B = cell; **T** = transistor; **IS** = impulse coil; **SS** = signal coil; **M** = magnet; **G** = counterpoise. When the permanent magnet passes over **SS** the induced current causes the transistor to conduct. The transistor thus closes the circuit containing the cell and the impulse coil, whose magnetic field then attracts magnet **M.** When **M** leaves the vicinity of coil **SS**, the induced current ceases and the transistor becomes open circuited, the cell current no longer circulates in the impulse coil, the magnetic field disappears. The magnet **M** only receives an impulse; it does not remain stuck to the coil. If the impulse is sufficient for **M,** turning on its arbor, to pass over the coil **SS**, again, the balance motion will be maintained as long as the life of the cell.

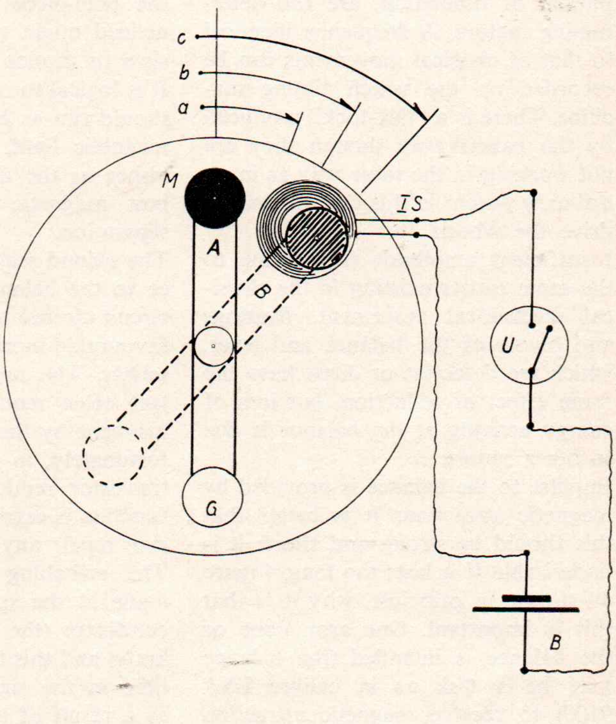


Fig. 48. Schematic circuit for the excitation of a magnetic coil using a mechanical contact. B = cell ; **U** = switch (mechanical contact; in practice actuated by means of the balance staff); **IS** = impulse coil; **M** = permanent magnet; **G** = counter-balance; **A** = position of **M** at the instant the circuit closes; **B** = position of **M** after passing over the centre of the coil. To have a large amplitude of oscillation of the balance, it is necessary that the impulse coil circuit is only closed through angle **a**. If the circuit remains closed through angle **b**, the attraction of the coil will be extended, and may act as a brake. If the contact **U** remains closed through angle **c** (position **B** of magnet **M**) the magnet will remain attracted to the centre of the coil and stay there. In practice this defect is revealed by the balance trembling, and not oscillating, or by a complete stoppage. In this event, the contact remains closed, but not firmly; it results in burning of the contact points, and rapid running down of the cell.

the magnetic attraction on the balance takes place for a very short time, but sufficient, however, to provide adequate amplitude to the balance.

Adjustment of calibres ESA 9000 and 9100 (ETA 2420, DAC 262)

The electronic version also has a balance and spring as the controlling element. The maximum accuracy in these movements—calibre ESA 9000 with normal mechanical contacts, and calibre ESA 9100 with transistorized switching—will be determined by the same laws applicable to a watch with a mechanical escapement. A well set balance-spring, and an adequate amplitude of oscillation, are the determining factors. A frequency identical to that of classical movements can be recorded on the watch timing machine. There is a "tick-tock" produced by the pallets even though they are not working in the same way as in an ordinary watch; in this case the pallets drive the wheels.

Insufficient amplitude is not due to the same causes existing in the classical mechanical movement. Bearings and pivots of the balance and lever, which are defective or dirty, have the same effect of reduction, but loss of energy arriving at the balance is due to other causes.

Impulse to the balance is provided by magnetic attraction. It is better that this should be strong and short; it is undesirable if it lasts too long. Figure **48** shows, in principle, why it is that this is important. One arm alone of the balance is intended (the balance may be a disk as in calibre ESA 9100) to receive magnetic attraction of the mass **M** with mass **G** as a counterbalance. **U,** which switches the circuit to coil **S** may be a mechanical contact or a transistor; it closes the circuit when **M** reaches the periphery of the coil (position **A**); the circuit must be opened again before the mass **M** attains the centre of the coil (position **B**). The angles **a, b** and **c** indicate the angular travel during which the circuit must be closed, or not. Longer closure of the contact does not increase the attraction, nor increase the amplitude but acts as a brake on the balance. If the magnetic field produced by the coil has not collapsed before **M** is exactly opposite the centre of the coil, the motion produced by the attraction will be retarded, or even reversed.

The rule is that the passage of current through the coil should be as short, and the distance between the coil and the mass, as small as possible. The amplitude does not increase if the current flows longer, but **M** should be as close to the coil as possible. The balance should thus turn true, and not have too much end-shake because contact with the coil could damage its turns (calibre ESA 9100). In calibres ESA 9000, ETA and DAC, there is no risk to the coils, on the contrary, the pole-pieces which become magnetized might touch the balance and slow its motion.

It is logical to request that the balance should run as close as possible to the magnetic field, since the force diminishes as the distance increases. The best magnetic insulator is physical separation.

The second requirement, with reference to the balance amplitude—that of circuit closure to be made at the most favourable moment—is not so easy to satisfy. The normal mechanical contact often requires very delicate adjustment by the watch-repairer. Here, fortunately, in calibre ESA 9100 the transistor renders great service. The function is carried out so well that during repair any adjustment is useless. The switching of the transistor is made at the speed of electrons in a conductor (the speed of light 300,000 km/s) and this takes place at the same time in the signal and impulse coils as a result of their relative positions. In mechanisms with a mechanical contact, excitation of the impulse coil is entirely dependent on the proper positioning, that is to say the curvature, of the contact blades. Electric wrist watches with normal mechanical contacts demand a great deal of knowledge and manual dexterity of the watch repairer.

Summing up, calibre ESA 9100 has the advantage of having a balance impulsed at a moment precisely determined by a transistor, which, fundamentally ensures a constant amplitude of balance oscillation. A small practical experiment shows the certainty with which this phenomenon takes place. Take out the pallets from the movement, and also remove the balance spring. Replace the balance, and connect the red wire and the white wire to the cell. The slightest motion given to the balance in either direction actuates the electrical circuit, which causes the balance to run like a motor. The speed of the balance quickly attains a considerable number of revolutions. Figure **47** may be considered as a sketch of a DC motor without contacts; it explains what takes place. If, following an initial external impulse the magnetic mass **M** passes above the signal coil **SS**, the transistor closes the circuit of the impulse coil **IS** and **M** is attracted. This impulse superimposed on the rotation of **M** (and of the counterbalance) suffices for the phenomenon of the coil **SS** to be repeated so that the masses (or the disks) are maintained in motion.

(Continued)

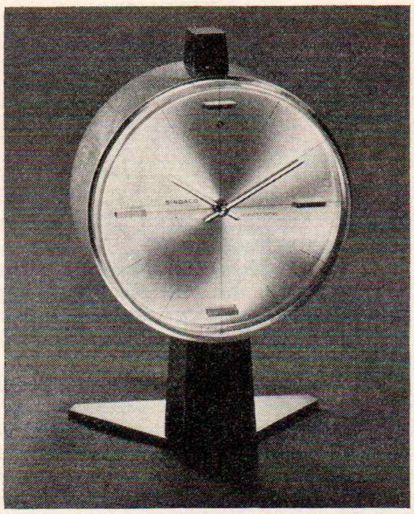


Fig. 49. This small table clock of very modern design is driven by a calibre ESA 9101 of Ebauches S.A. it is part of the range of Sindaco S.A. at Locarno.