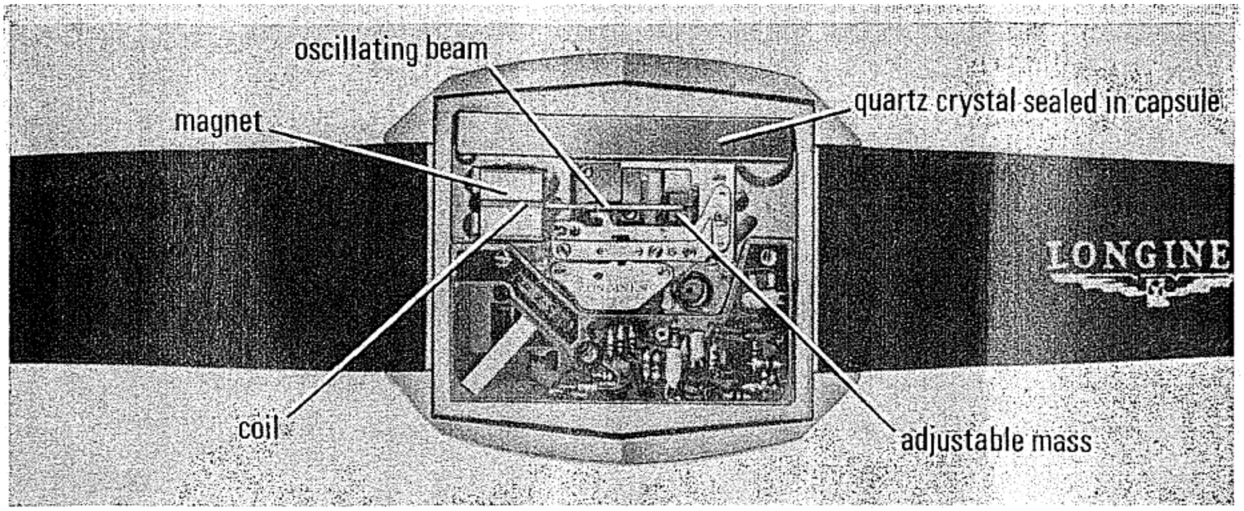


1. Neat layout of the Longines quartz-controlled wrist-watch movement. The quartz crystal controls an electromechanical oscillator, this being the 'motor' which drives the watch. The battery fits at lower left as shown here.

The ultimate watch?

Should you desire a watch with accuracy guaranteed to within 60 seconds over 12 months, then read on. Longines have produced such a paragon: a quartz-controlled timepiece that will be in the shops by Christmas

by Roger Livesey

Though the cost is high, and the market thus limited, the search for ever more accurate wrist watches continues with increasing fervor. Recently a pair of Quartzchron watches, 2, arrived in the UK from Longines of Switzerland, the makers, setting a new standard in guaranteed accuracy from a timepiece of wrist-watch size—the Quartzchron is guaranteed to keep time within 60 sec over twelve months; in practice it generally achieves better than this, it is claimed.

The watch is the result of development of quartz-controlled timepieces by Longines over many years, the start of the line being a box weighing about 264 lb in the days of 'valves'—used for accurate timing of sporting events. Transistors and printed circuits made for a slightly smaller box, then a reasonably-sized table clock, and then a prototype pocket watch only 5 cm by 5 cm by 1 cm. The overall dimensions of the new wrist watch are 48-35 mm by 42-3 mm by 14-2 mm. It weighs only

24 oz, including the leather strap. The movement is 33mm by 28-4mm by 51mm.

In the conventional watch, the reference by which time is measured is a mechanical oscillator — a carefully balanced wheel acting against a spring. The oscillations are maintained by another tensioned spring (the main spring) acting through an escapement. Such watches are capable of keeping time to within a minute a week (for a really accurate one see Engineering, vol. 208, 19/26 Dec 1969). Although quartz- controlled timepieces are usually known as 'electronic', the reference is again basically mechanical, being a carefully cut block of quartz which will have a natural resonant frequency determined by its dimensions. Such a block is stressed if an electrical potential is applied across it, and the oscillations can therefore be sustained electrically. Driven by a carefully designed electronic circuit the frequency stability—timekeeping ability—of such a device can be extremely high. It is widely used to stabilize frequency in radio equipment.

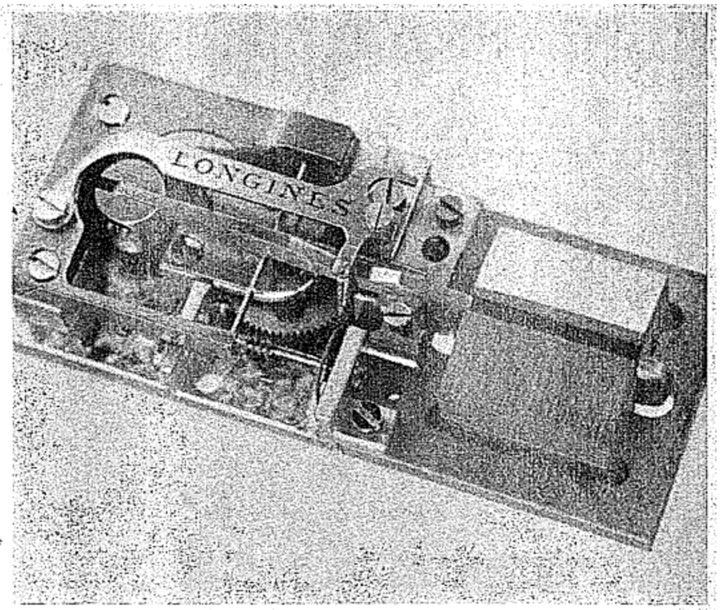
Applying such a system in a wrist watch raises one particularly difficult problem: the transition from a very accurate electrical signal to an accurate mechanical movement to drive the usual watch hands. One solution is to successively divide the high frequency of the quartz oscillator until a frequency low enough to drive some kind of synchronous electric motor is obtained. In a large device this is possible, but the large number of electronic components required, and the high resultant electrical current consumption, prevent successful use of such a technique in a wrist watch powered by a necessarily small battery.

The solution adopted in the Longines watch is ingenious. The hands of the watch are driven directly by an electromechanical oscillator, which is inherently reasonably accurate, presumably of the same order as the 'tuning fork' watches in which an electromechanical oscillator is the basic reference (an electromagnetically driven 'tuning fork'). Such watches can keep time to within a minute a month or so, several times better than a high quality mechanical timepiece. In the Quartzchron the frequency of the electromechanical oscillator is compared with that of a quartz-controlled oscillator, and the error signal produced is used to correct the frequency of the electromechanical device. In this way frequency stability, or timekeeping ability, can be increased by another order of magnitude. As the quartz oscillator is used only for comparison, not as a drive, the circuits can be considerably simplified and the current consumption can be much lower, maximum in the Longines watch being l0A.

A symbolic diagram of the watch is shown in 5. The quartz bar resonates at a frequency of 8,500 c/s. and an electrical signal of this frequency is fed to the comparator. The electromechanical oscillator—the 'motor'—oscillates at 170 c/s, and an electrical signal of this frequency is also fed to the comparator; this checks there is one oscillation of the 'motor' for every 50 oscillations of the quartz crystal; any deviation by the 'motor' results in an error 'signal from the comparator. This signal is' applied to the drive circuits for the 'motor' to keep the frequency at 170 c/s.

Coupling of the electro-mechanical oscillator to the watch hands is simple: The 0.111 mm amplitude oscillation drives pawls which act on a wheel with 170 0.024 mm high teeth cut in its

2. First version of the watch. Later versions have the 'winder' knob recessed in the back.



3. Electromechanical 'oscillator' motor: the coil and magnet on the right the toothed wheel drives the second hand through a worm gear.

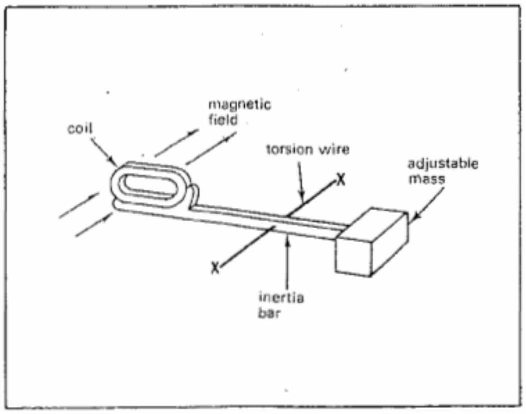
perimeter. The wheel thus rotates at one revolution per sec and drives the second hand. The minute, hour and date indicators are driven through gears.

The 'motor' itself is extremely simple. It consists of a torsion wire carrying a relatively heavy bar, 4. At one end of the bar is an adjustable mass, at the other a small coil of wire. The coil (2,200 turns of 0.013 copper wire) is placed in a magnetic field and the motor sustaining circuits apply a signal to keep the bar vibrating. The vibrating coil also produces an electrical output signal which is fed to the comparator so that correction may be applied to the drive signal, as previously explained. Precision is ±0.3 sec/day, resulting in an expected accuracy of better than 1 mm a year when worn. Oddly enough, in this age of integrated circuits, and even 'large scale integration' the electronic circuits of the Longines watch are built from individual components mounted on a small printed circuit board. The circuits include 40 components in all: 14 transistors, 19 resistors and seven capacitors. The reason that Longines have not used an integrated circuit is not really clear. Their sales brochure says their solution 'has made it possible to do without integrated circuits requiring the use of specific equipment so complex that it is accessible only to laboratories or highly specialized manufacturers'. By this they presumably mean that they do not have such facilities. I wonder if they have spoken to Plessey, or any other manufacturer who develops ICs to specification. As can be seen front the picture of 'the works', 1, further miniaturization of the electronic circuits could result in a considerable reduction in overall size of the watch. At present it is perhaps just a little larger than the usual high quality chronometer.

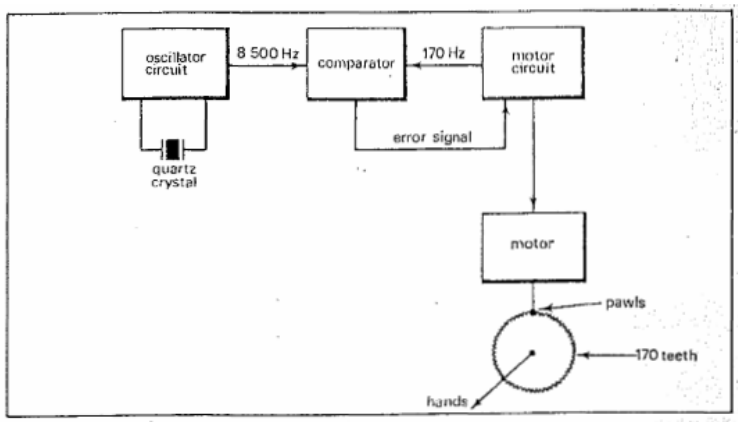
The watch shown in the frontal photograph, 2, is a 'first generation' model, the only one available in the UK as I am writing this. It is intended to have about another dozen here in time for Christmas. The 'second generation' is slightly different, from the outside principally in that the crown (or winder to the layman) for setting time and date, will not be on the side, as shown in 2, but recessed into the rear.

The internal arrangement is also very different, the layout being much 'neater' in the later version. In fact, the basic movement was developed by Longines as a joint venture with other Swiss watchmakers. The latest movement, I and 3, is Longines' own development The watch is powered by a small cell under a screw cap inserted from the back, this battery (1.35 V, 150 mAh) being sufficient to power the watch over a period of about 18 months.

At present prices are high, and they are not expected to drop significantly in the short term, but for those who can afford it Watches of Switzerland of Bond Street, London, and possibly in other major cities, might be able to get you the watch in time for Christmas. In stainless steel on a black leather strap, it costs £350. In 18 ct gold it costs £750, or £1,350 with a gold bracelet.



4. Mechanical oscillator is a magnetically driven beam supported on a torsion wire.



5. The frequency of the oscillating motor is compared wish that of a quartz crystal oscillator, any error being used to correct the 'motor' frequency.