Essl 290 2021

Lecture 39

Mon. 1st draft paper

Weds: Barnett: 154 – 160

Quartz clock development

Quartz clock development was initiated by

* radio communication
* telephone communication

and both of these developed rapidly in the period 1900 - 1920. In both cases the signal (conversation, radio program) was carried by an electromagnetic carrier wave. Then different channels of communication would be assigned different frequencies. These frequency ranges cannot overlap otherwise there would be interference between different radio stations.

carrier 605 kHz

range 600 kHz → 610 kHz

station 1

carrier 615 kHz

range 610 kHz → 620 kHz

station 2

Thus radio stations would have had to:

* measure their carrier frequency
* control their carrier "

This means that they would have needed precision measuring instruments to do this. Particularly they needed a device that would generate a well-known precise frequency (this is called a frequency standard)

How was this arranged? In the United States

Radio communications regulated by the Federal Communications Commission (FCC)

→ 1927 stay within 500Hz of carrier frequency

Lombardi IEEE Instrumentation... Oct 2011

1932 stay within 50Hz of carrier frequency

The carrier frequencies are about 1000kHz. Thus these specifications require that the frequency error would only be

1927: $\frac{500}{1000000} = \frac{1}{2000}$ ⇝ 0.05% error ⇔ 99.95% accuracy

1932 $\frac{50}{1000000} = \frac{1}{20000}$ ⇝ 0.005% error ⇔ 99.995% "

Q: Which entities would have wanted ~~such~~ devices to regulate frequency with such precision?

Fundamentally there are two types of entity

1) government ⇝ regulate multiple independent users (e.g. radio stations, ...

2) private communication companies ⇝ regulate multiple users on the company system.

Actual efforts to develop this were spearheaded in the following places:

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Katzir AmSci 73, 1-35 (2016)

Initial investigations at academic institutions

* Walter Cady at Wesleyan University
  - developed a stable, very precise quartz osillator. (1919-1920)
  - patented in 1920
* George Pierce at Harvard Univ
  - improved Cady's work
  - higher frequencies available ~> 20 000kHz
  - simpler circuitry

Academia

Adoption + refinement by government entities:

* National Bureau of Standards (US)
  - developed frequency standard with accuracy 99.999% (1929)

Demo: NIST page (1929)

* National Physical Laboratory (UK)
  - government laboratory
  - regulated radio transmission
  - naval uses

government

Adoption + refinement by corporate entities:

* Western Electric and AT+T (US)
  - William Marrison + Joseph Horton
  - converted frequency standard into a clock (1927)

Demo. Lambardi paper.

  - accuracy 1 part per million

business / industry

By the late 1930s portable versions of quartz clocks had been developed.

Lombardi For example the Rohde + Schwarz clock (1938) would be inaccurate by at most 0.004s per day (0.000005% error). By the 1950s such quartz oscillators were accurate to an error of at most 1.0×10^{-8} %.

Q: Do these appear intended for daily use by ordinary people?

Q: What might have resulted in the migration of clocks quartz into ordinary clocks?

Quartz watches

Electronic watches were first developed in the 1960s. The first commercial watch of this type used a tuning fork - the Bulova Accutron.

This posed a threat to the Swiss watch industry, then selling about half of the world's watches. Swiss watchmaking companies set up a company called CEH. This produced the world's first prototype quartz wristwatch (Betal, 1967). These prototypes did not result in commercial success.

However, the Seiko Company (Japan) introduced the first successful commercial quartz wristwatch, the Seiko Astron in 1969.

* luxury product, costing as much as a small car.

Demo Seiko site.

These quartz wristwatches rapidly improved, specially

* more efficient battery use (multiple years)
* smaller sizes
* varied displays.

The market for such watches came to be dominated by Japanese companies. and Swiss watch companies have still not regained their traditional dominance.

	Switzerland 1000s of units	Japan 1000s of units
1974	84,416	32,369
1980	50,986	87,889

Londes

Lombardi The accuracy of cheap quartz watches is now about 0.5s per day. The best quart watches about 0.03s per day.

These watches are ubiquitous ~ about 1.2 billion manufactured in 2005

~~Q: Where else~~

~~Q: Why day~~

Q: Do you use a quartz watch? If so why did you choose it?

Q: Do you use quartz timers? Are they important for your daily life?