LSI for Radio Clocks

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Radio clocks sustain accurate time at all times, as they are equipped with functions for receiving low frequency signals (the standard-time and frequency-signal emission) that carry time information and automatically correct time and calendars. Products fitted with a radio clock function are on the increase, since the broadcast range of the standard frequency was extended to cover all Japan in 2001, which resulted in radio clocks getting into the limelight.

Conventional radio clocks were used as ordinary clocks (table clocks, watches, wall clocks, etc.) but with the recent improvement of LSIs for radio receiver and antennas combined with a reduction in power consumption, raised sensitivity and miniaturization, application of the device in various products is anticipated, such as consumer appliances, mobile devices and home electric appliances.

This paper will provide a general summary of the "ML6191", a real-time clock LSI with an automatic time correction function that is a combination of the RF for the standard frequency and a real-time clock in a single chip, developed by Oki Electric Industry, as well as examples of system applications and future efforts.

About standard-time and frequency-signal emission

The standard frequency is a low frequency signal that carries time information (time code). The time error of this signal is approximately one second in 100,000 years, which is extremely high accuracy. The standard frequency transmitting stations are located at major regions on a global scale, such as Japan, Germany, United Kingdom, North America and China (Figure 1).

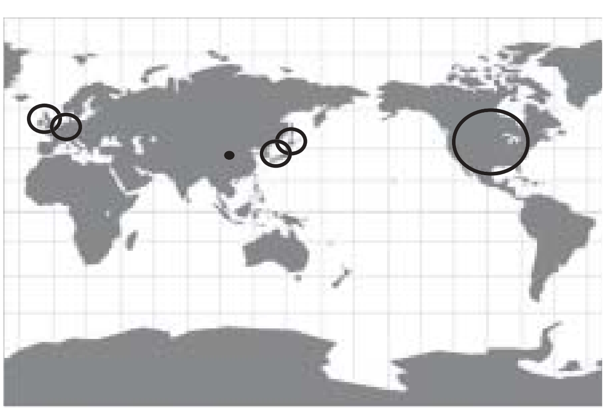

Fig. 1 Low frequency standard frequency broadcasting stations and worldwide coverage.

The broadcasting of time information is conducted in Japan by the National Institute of Information and Communications Technology, an incorprated administrative agency, with the standard frequency transmitting offices established at two locations including Ohtakado-yama standard frequency station in Fukushima Prefecture (1997) and Hagane-yama standard frequency station in Saga Prefecture (2001). Each transmitting station covers a radius of 1,200km and the two transmitting stations combined cover almost the entire area of Japan (Figure 2). Further, mutual interference is avoided with different frequencies assigned, 40KHz from Ohtakado-yama station (Fukushima-Pref.) and 60KHz from Hagane-yama station (Saga-Pref.).

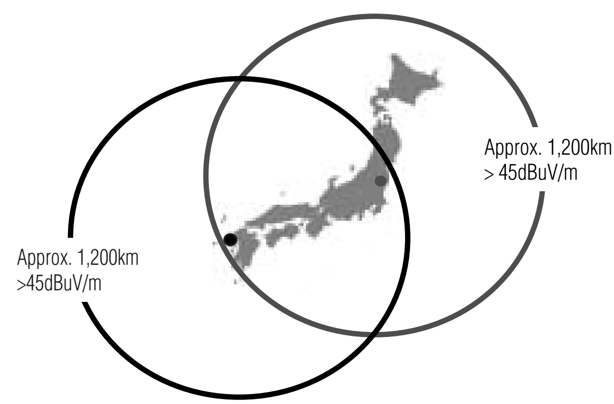

Fig. 2 Low frequency standard frequency broadcasting stations and their range of coverage.

The time code carried by the standard frequency is composed of 60-bit (60 seconds) data. The time indicated by this time code and its data format varies from country to country. Figure 3 shows the Japanese time code format,

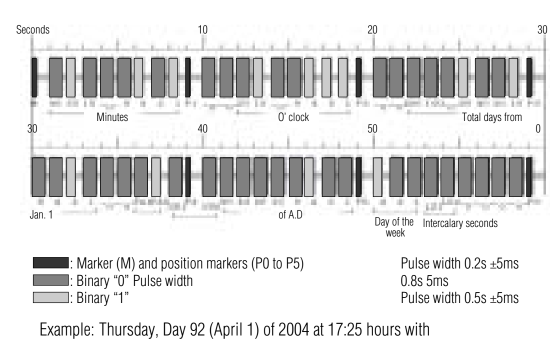

Fig. 3 Japanese time code format [1)]

which indicates the “0”, “1” and marker data with 1-bit signals. Further, the marker expresses the time synchronization position every ten seconds and the separation of digit data.

Mechanisms of radio clocks and issues relating to system configurations

A radio clock is composed of a radio receiver, decoder, timer clock and display which are generally created through the combination of two LSIs, one of which is used for RF and the other for a microcomputer (Figure 4).

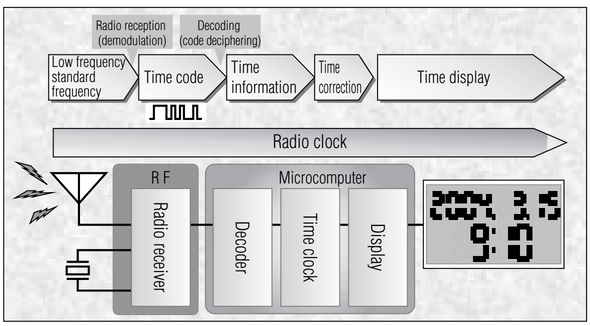

Fig. 4 Radio clock configuration.

- Radio receiver: The low frequency signal sent by the standard frequency transmitting station is received and the time codes are output as digital signals (TCO signal).
- Decoder: TCO signals are read, time information is extracted based on the time data format, validation of the time data is verified and the received time is determined.
- Time clock: Determined time data is reflected on the clock and sustains the clock function.
- Display: Time being clocked internally is displayed on a display such as an LCD panel.

There are two major issues with the radio clock relating to the configuration of the system.

The first is the fact that a few minutes are required to start receiving the time code to determine the time, as the transmission of the utilized time code takes 60 seconds. This means that the microcomputer that controls the radio clock must maintain the RF turned to ON and scan the signal level of the TCO signal in a few tens of milliseconds to determine the bit data and also verify the validation of the digit data, all during the few minutes it takes to receive the time code. For this reason the power consumption is lowered for the microcomputer and the RF, operating for the duration of a few minutes at a time.

The other issue is the fact that the quality of time data extracted is directly influenced by the receiver sensitivity. The limit for radio clocks to receive a weak standard frequency is determined by the performance of the antenna and the radio reception circuit used. However, since radio receiving can be inhibited by noise it is difficult to determine with any certainty the information of the correct time even when reception of just a single bit of data in the TCO signal is inhibited. In other words the improvement of reception sensitivity through the implementation of noise countermeasures is the largest issue on hand for the purpose of system configuration.

Relationship between noise and reception sensitivity

When the strength of a radio wave signal is defined as the signal (S) and the strength of noise is defined as the noise (N), the reception sensitivity of a radio clock for practical purposes is the extent to which the S/N ratio can be reduced while the clock continues to receive signals. A correlation chart showing the variance of the S/N ratio of the TCO signal waveform in four steps is shown in Figure 5.

There is no deformity with the TCO signal waveform using waveform A, which displays the largest S/N ratio. When the S/N ratio is lowered to waveform B the spiked deformity arising from noise starts to show, while with waveform C starts to break down as the frequency and extent of the deformity increases. By the time the deterioration reaches waveform D the deformity is so extensive the original shape of the waveform is no longer identifiable. Further, an overall review indicates that there is no regularity as to the occurrence of deformity due to noise.

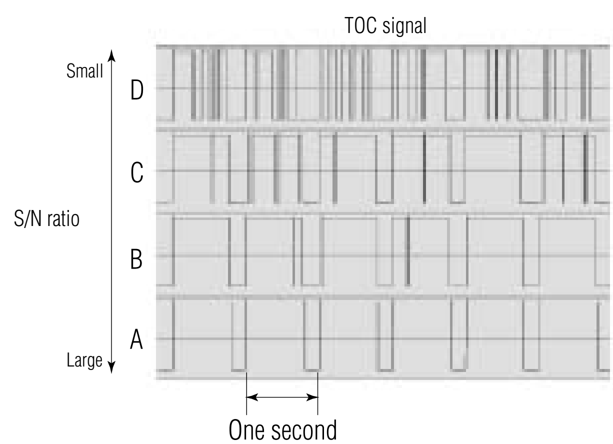

Fig. 5 Correlation chart of the S/N ratio and TCO signal waveform.

The ability of a radio clock to extract time information from even a TCO signal waveform that has deteriorated in quality, due to the low S/N ratio as shown in waveform D, would lead to an improvement in the reception sensitivity of the clock for practical purposes. For this reason it is necessary to incorporate a noise reduction filter when configuring the system in order to bring the waveform closer to that of waveform A. The noise reduction filter used for this purpose removed the noise of small spiked shapes by assigning low-pass characteristics to the filter.

In reality, however, partial abnormalities occur with waveforms due to reflected waves and such, which leave remnants of noises that cannot be removed even with a noise reduction filter. This in turn results in erroneous interpretation of data bits in decoded signals, such as data “0”, data “1” or a marker. It is necessary to implement a regulative data bit in order to correct such erroneous interpretation of data bits and turn it into normal data.

There are a variety of methods used to correct data bits, such as those that utilize the regularity of data. This is when individual manufacturers draw on their unique know-how.

This means that it would not be an exaggeration to say that the improvement of noise resistance and reception sensitivity, made possible through noise reduction filters and data bit regulative technologies, is directly proportional to the commercial value of radio clocks.

Summary of ML6191

The ML6191 is an LSI for radio clocks and a real-time clock LSI that incorporates a radio receiver, decoder and timer clock inside a single chip to make it possible to control radio receiver, and the time setting of clocks through serial communications conducted from a main external CPU (Photo 1).

Phot. 1 The ML6191.

Major features of this LSI are as follows:

- Low consumption current of 0.3μA while the chip is in the HALT mode is attained through the adoption of the SOI process and a high average sensitivity of 1.0μVrms.
- Improvement of reception sensitivity has been achieved through high noise resistance using a noise reduction filter and data regulative technology from proprietary technological know-how matured by past product developments.
- With the adoption of a command interface it is easy to control from a main CPU via a serial port, similar to that of real-time clock ICs.

Through these practical reception sensitivity was achieved whenever the S/N ratio deteriorated and as a result it is possible to automatically correct the time using a standard frequency while sustaining accurate time. Furthermore, by using it as a real-time clock IC, not only is the load on the main CPU be reduced but it is also be possible to keep the number of parts and components to a minimum when configuring the system. So far the ML6191 has been offered as a Japanese version LSI series for radio clocks used in Japan. A version compatible for Germany is currently under development.

Main specifications of the ML6191 JJY version are as follows:

- Automatic start and stop of reception.
- Reception start time and reception interval time can be set.
- Automatic switchover between the signals of two frequencies (40/60KHz).
- Selectable reception modes (Auto/Manual).
- Selectable time systems (12/24 hours).
- Clock output (32.768KHz).
- Internally set time (Japan time).
- Four-wire serial interface.
- High sensitivity with typical reading of 1.0μVrms.
- Low voltage operation of 1.1 to 3.6V.
- Low electric current consumption of 0.3μA in the HALT mode (operating at 32KHz in standby mode of radio receiving).
- Temperature range of -40 to +85°C.

Application implementation examples

The ML6191 is optimally suited for applications that require a low voltage and low current consumption besides accurate time for devices that require time settings (Figure 6).

More specifically, examples of such applications are used in products that require sustained accurate time, such as “broadcast program recordings” or “time stamp functions”, including audiovisual equipment, such as video recorders and DVD recorders, as well as consumer appliances, such as digital cameras and video cameras, or security equipment, such as surveillance cameras, or industrial equipment, such as fax machines and time recorders.

As seen from the perspective of time setting operations it is possible to use this LSI for products with which “time setting operations are conducted after the system is switched from a standby condition to an

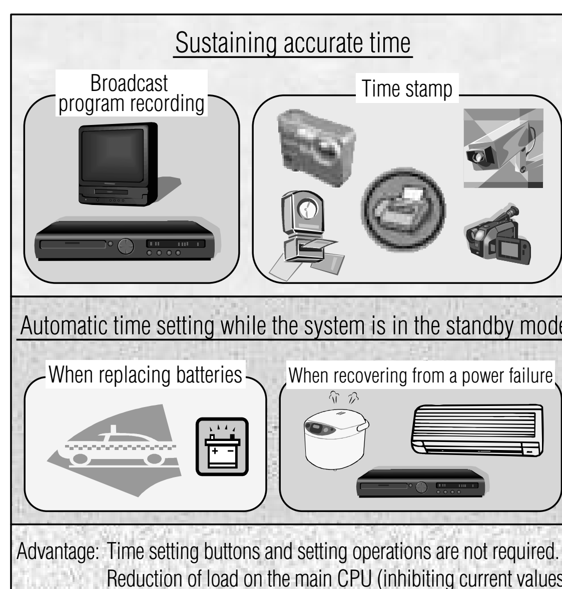

Fig. 6 Applications and purpose of the ML6191.

operating condition" following the replacement of batteries or recovery from a power failure, such as the fare meter on taxi cabs, rice cookers and even household fixtures, such as air conditioners.

Future of radio clocks and development of derivatives from radio clock LSIs

The biggest advantage for using the ML6191 is the automation of time setting operations with the ultimate purpose of eliminating the setting of time manually and also thereby reducing the load on the main CPU. If it becomes possible to eliminate a time setting button a new dimension in product developments can be expected as it would be possible, for example, to create "even simpler operations" for products for senior citizens, who tend to find it difficult dealing with the operation of products as well as "much safer" products for naturally curious infants. Therefore, there are many, many applications for which this radio clock LSI could be implemented and in the future we could also expect further increases in demand for radio clock LSIs.

Time signals provided by "analog broadcasts" domestically may disappear in2011, as they are switched to land-based digital broadcasts. This signifies that television sets and video products that were utilizing these time signals to regulate the internal clocks will need to change the methods used. As an alternative use of the time information included in a digital broadcast, GPS, time server or other means for regulating the time are being considered. Yet in each case, however, there will be a need to conduct time setting operations from the main CPU after the system is switched from a standby condition to an operating condition.

It is for this reason we hope to see the spreading of the practice to mount radio clock LSIs, which puts absolutely no load on the main CPU, are least energy consuming and economical, yet can be installed easily.

Similar to Japan, the mounting of radio clock LSIs overseas can be anticipated in countries, such as Germany, the United Kingdom and the United States, which are already broadcasting standard frequencies. Additionally, the broadcasting of a standard frequency is also planned in China where the scale of the market that uses radio clock LSIs is expected to expand in an explosive manner in the future.

The development of the radio clock LSI at Oki Electric will involve the implementation of time formats of other countries, as well as the development of LSI derivative products through the incorporation of more functions (Table 1). Developments for a German time format is currently ongoing, while efforts will be made to comply with the UK, US and Chinese versions to ensure the mounting of radio clock LSIs are on a global scale.

Further, for the purpose of implementing functions we intend to add an interface with the main CPU (12C serial interface, etc.) and offer individual functions (switch input, temperature measurements, remote control reception, LCD display, etc.) with the radio clock LSI added to those application functions that are currently realized with sub-micro-computers, to facilitate further miniaturization and reduce the costs of the systems.

Table 1 Development of radio clock LSI derivatives.

Purpose	Contents	Remarks
Development of LSIs for overseas markets by complying with other time formats	UK version	Japan version (already developed)
	US version	Germany version (under development)
	China version	
Incorporation of sub-micro-computer functions by implementing additional functions	I2C serial interface	4-wire serial interface (already developed)
	Temperature measurement	
	Power monitoring	
	Switch input	
	Remote control reception	
	LCD display, etc.	

Furthermore, we would like to propose radio clock LSI application system development solutions to customers who are seeking to build their individual radio clock system in a timely manner.

References

1) Japan Standard Time Group of the National Institute of Information and Communications Technology (NICT): URL http://www.nict.go.jp/overview/index-J.html

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