Radio clock

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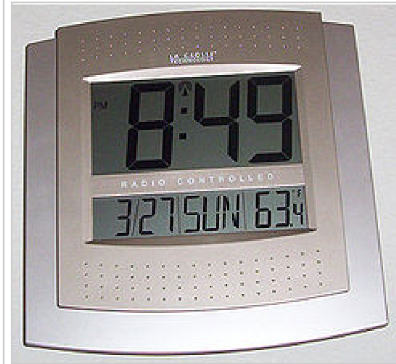


A modern LF radio-controlled clock

A **radio clock** or **radio-controlled clock** (**RCC**) is a clock that is automatically synchronized by a time code transmitted by a radio transmitter connected to a time standard such as an atomic clock. Such a clock may be synchronized to the time sent by a single transmitter, such as many national or regional time transmitters, or may use multiple transmitters, like the Global Positioning System. Such systems may be used to automatically set clocks or for any purpose where accurate time is needed.

One common style of radio-controlled clock uses time signals transmitted by dedicated terrestrial longwave radio transmitters, which emit a time code that can be demodulated and displayed by the radio controlled clock. The radio controlled clock will contain an accurate time base oscillator to maintain timekeeping if the radio signal is momentarily unavailable. Other radio controlled clocks use the time signals transmitted by dedicated transmitters in the shortwave bands. Systems using dedicated time signal stations can achieve accuracy of a few tens of milliseconds.

GPS satellite navigation receivers also internally generate accurate time information from the satellite signals. Dedicated GPS timing receivers are accurate to better than 1 microsecond; however, general-purpose or consumer grade GPS may have an offset of up to one second between the internally calculated time, which is much more accurate than 1 second, and the time displayed on the screen.

Other broadcast services may include timekeeping information of varying accuracy within their signals.

Contents

Single transmitter

Radio clocks synchronized to terrestrial time signals can usually achieve an accuracy within a hundredth of a second relative to the time standard,[1] generally limited by uncertainties and variability in radio propagation.

Longwave and shortwave transmissions

Radio clocks depend on coded time signals from radio stations. The stations vary in broadcast frequency, in geographic location, and in how the signal is modulated to identify the current time. In general, each station has its own format for the time code.

List of radio time signal stations

List of radio time signal stations

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
25 kHz	RJH69	Belarus	Vileyka (54° 28' 8 *N* *26° 46' 23* E)	3 umbrella antennas, fixed on 3 guyed tubular masts, insulated against ground with a height of 305 metres and 15 guyed lattice masts with a height of 270 metres		
25 kHz	RJH77	Russia	Arkhangelsk (64° 21' 51 *N* *41° 33' 52* E)	3 umbrella antennas, fixed on 18 guyed lattice masts, height of central masts: 305 metres		
25 kHz	RJH63	Russia	Imeretinskaya (44° 46' 25 *N* *39° 32' 50* E)	umbrella antenna, fixed on 13 guyed lattice masts, height of central mast: 425 metres		
25 kHz	RJH99	Russia	Nizhny Novgorod (56° 10' 20 *N* *43° 55' 38* E)	3 umbrella antennas, fixed on 3 guyed tubular masts, insulated against ground with a height of 205 metres and 15 guyed lattice masts with a height of 170 metres		
25 kHz	RJH66	Kyrgyzstan	Bishkek (43° 2' 29 *N* *73° 37' 9* E)	3 umbrella antennas, fixed on 18 guyed lattice masts, height of central masts: 276 metres		
25 kHz	RAB99	Russia	Chabarowsk (48° 29' 29 *N* *134° 48' 59* E)	umbrella antenna, fixed on 18 guyed lattice masts arranged in 3 rows, height of central masts: 238 metres		

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
40 kHz	JJY	Japan	Mount Otakadoya, Fukushima (37° 22' 21 *N* *140° 50′ 56* E)	Capacitance hat, height 250 m	50 kW	[2] Located near Fukushima and from Mount Hagane (located on Kyushu Island)
50 kHz	RTZ	Russia	Irkutsk (52° 25' 41 *N* *103° 41′ 12* E)		10 kW [3]	Inactive
60 kHz	JJY	Japan	Mount Hagane, Kyushu (33° 27' 54 *N* *130° 10′ 32* E)	Capacitance hat, height 200 m	50 kW	[2] Located on Kyūshū Island
	WWVB	United States	Near Fort Collins, Colorado[4] (40° 40' 41 *N* *105° 2′ 48* W)	Two capacitance hats, height 122 m	70 kW	[2] Received through most of mainland USA
	MSF	United Kingdom	Anthorn (54° 54' 27 *N* *3° 16′ 24* W)	Triple T-antenna, spun 150 metres above ground between two 227 metres high guyed grounded masts in a distance of 655 metres	17 kW	Range up to 1500 km. Before 1 April 2007, the signal was transmitted from Rugby, Warwickshire (52° 21' 33 *N* *1° 11′ 21* W)
66.66 kHz	RBU	Russia	Taldom, Moscow (56° 43' 59 *N* *37° 39′ 47* E)	umbrella antenna, fixed on a 275 metres high central tower insulated against ground and five 257 metres high lattice masts insulated against ground in a distance of 324 metres from the central tower	10 kW	before 2008, transmitter located at 55° 44' 14 *N* *38° 9′ 4* E

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
68.5 kHz	BPC	China	Shangqiu, Henan (34° 56' 54 *N 109° 32′ 34* E)	4 guyed masts, arranged in a square	90 kW	21 hours per day, with a 3-hour break from 05:00–08:00 (China Standard Time) daily (21:00–24:00 UTC)[5]
75 kHz	HBG	Switzerland	Prangins (46° 24' 24 *N 6° 15′ 4* E)	T-antenna spun between two 125 metres tall, grounded free-standing lattice towers in a distance of 227 metres	20 kW	Discontinued as of 1 January 2012
77.5 kHz	DCF77	Germany	Mainflingen, Hessen (50° 0' 58 *N 9° 0′ 29* E)	Vertical omni-directional antennas with top-loading capacity, height 150 m [6]	50 kW	[2] Located southeast of Frankfurt am Main with a range of up to 2000 km[7]
	BSF	Taiwan	Zhongli (25° 0' 19 *N 121° 21′ 55* E)	T-antenna spun between two telecommunication towers in a distance of 33 metres		[8]
100 kHz	BPL	China	Pucheng, Shaanxi (34° 27' 23 *N 115° 50′ 13* E)	single guyed lattice steel mast	800 kW	LORAN-C compatible format signal on air from 5:30 to 13:30 UTC,[9] with a reception radius up to 3000 km[10]

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
162 kHz	TDF	France	Allouis (47° 10' 10 *N 2° 12′ 16* E)	Two guyed steel lattice masts, height 350 m, fed on the top	2000 kW	AM-broadcasting transmitter, located 150 km south of Paris with a range of up to 3500 km, using an encoding similar to that of DCF77, but requiring a more complex receiver as time signal is transmitted by phase modulation
198 kHz	BBC Radio 4	United Kingdom	London (51.518409°N 0.143691°W)	Droitwich uses a T-aerial suspended between two 213 m guyed steel lattice radio masts, which stand 180 m apart from each other.	500 kW[11]	Transmission towers at Droitwich (500 kW), Burghead (50 kW) and Westerglen (50 kW). The time signal is transmitted by 25 bit/s phase modulation.[12]
2.5 MHz	BPM	China	Pucheng, Shaanxi (34° 56' 54 *N 109° 32′ 34* E)			7:30-1:00 UTC[13]
	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N 105° 2′ 48* W)		2.5 kW	Binary-coded decimal (BCD) time code on 100 Hz sub-carrier
	WWVH	United States	Kekaha, Hawaii (21° 59' 16 *N 159° 45′ 46* W)		5 kW	

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
3.33 MHz	CHU	Canada	Ottawa, Ontario (45° 17' 40 *N 75° 45' 27* W)		3 kW	300 baud Bell 103 time code
4.996 MHz	RWM	Russia	Moscow (55° 44' 14 N 38° 9' 4 E)		5 kW [3]	SSB
5 MHz	BPM	China	Pucheng, Shaanxi (34° 56' 54 N 109° 32' 34 E)			0:00-24:00 UTC[13]
	BSF	Taiwan	Zhongli			[14]
	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N 105° 2' 48* W)		10 kW	BCD time code on 100 Hz sub-carrier
	WWVH	United States	Kekaha, Hawaii (21° 59' 16 *N 159° 45' 46* W)		10 kW	
	HLA	South Korea	Taejon (36° 23' 14 *N 127° 21' 59* E)		2 kW	
	LOL1	Argentina	Buenos Aires		2 kW	
	YVTO	Venezuela	Caracas		1 kW	
7.85 MHz	CHU	Canada	Ottawa, Ontario (45° 17' 40 *N 75° 45' 27* W)		10 kW	300 baud Bell 103 time code
9.996 MHz	RWM	Russia	Moscow (55° 44' 14 N 38° 9' 4 E)		5 kW [3]	SSB
10 MHz	BPM	China	Pucheng, Shaanxi (34° 56' 54 N 109° 32' 34 E)			0:00-24:00 UTC[13]
	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N 105° 2' 48* W)		10 kW	BCD time code on 100 Hz sub-carrier

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
	WWVH	United States	Kekaha, Hawaii (21° 59' 16 *N 159° 45' 46* W)		10 kW	
	LOL1	Argentina	Buenos Aires		2 kW	Observatorio Naval
	PPE[15]	Brazil	Rio de Janeiro[15]	Horizontal half-wavelength dipole[15]	1 kW[15]	
11 MHz	ATA	India	New Delhi, National Physical Laboratory of India			
14.67 MHz	CHU	Canada	Ottawa, Ontario (45° 17' 40 *N 75° 45' 27* W)		3 kW	300 baud Bell 103 time code
14.996 MHz	RWM	Russia	Moscow (55° 44' 14 N 38° 9' 4 E)		8 kW [3]	SSB
15 MHz	BPM	China	Pucheng, Shaanxi (34° 56' 54 N 109° 32' 34 E)			1:00-9:00 UTC[13]
	BSF	Taiwan	Zhongli			[14]
	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N 105° 2' 48* W)		10 kW	BCD time code on 100 Hz sub-carrier
	WWVH	United States	Kekaha, Hawaii (21° 59' 16 *N 159° 45' 46* W)		10 kW	
20 MHz	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N 105° 2' 48* W)		2.5 kW	BCD time code on 100 Hz sub-carrier

Frequency	Callsign	Country	Location	Aerial type	Power	Remarks
25 MHz	WWV	United States	Near Fort Collins, Colorado (40° 40' 41 *N* *105° 2' 48* W)	Broadband monopole	1.0 kW	Schedule: variable (experimental broadcast)
	MIKES	Finland	Espoo, Finland (60°10'49"N 24°49'35"E)	λ/4 sloper antenna	200 W[16]	Amplitude modulation similar to DCF77

A current list of times signal stations is published by the BIPM as an appendix to their annual report; the appendix includes coordinates of transmitter sites, operating schedules for stations, and the uncertainty of the carrier frequency of transmitters.[17][18] Many other countries can receive these signals (JJY can sometimes be received in New Zealand, Western Australia, Tasmania, and the Pacific Northwest of North America at night), but success depends on the time of day, atmospheric conditions, and interference from intervening buildings. Reception is generally better if the clock is placed near a window facing the transmitter. There is also a propagation delay of approximately 1 ms for every 300 km the receiver is from the transmitter.

Clock receivers

A number of manufacturers and retailers sell radio clocks that receive coded time signals from a radio station, which, in turn, derives the time from a true atomic clock.

One of the first radio clocks was offered by Heathkit in late 1983. Their model GC-1000 "Most Accurate Clock" received shortwave time signals from radio station WWV in Fort Collins, Colorado. It automatically switched between WWV's 5, 10, and 15 MHz frequencies to find the strongest signal as conditions changed through the day and year. It kept time during periods of poor reception with a quartz-crystal oscillator. This oscillator was disciplined, meaning that the microprocessor-based clock used the highly accurate time signal received from WWV to trim the crystal oscillator. The timekeeping between updates was thus considerably more accurate than the crystal alone could have achieved. Time down to the tenth of a second was shown on an LED display. The GC-1000 originally sold for US$250 in kit form, US$400 preassembled, and was considered impressive at the time. Heath Company was granted a patent (http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=4582434.PN.&OS=PN/4582434&RS=PN/4582434) for its design.[19][20]

In the 2000s (decade) radio-based "atomic clocks" became common in retail stores; as of 2010 prices start at around US$15 in many countries.[21] Clocks may have other features such as indoor thermometers and weather station functionality. These use signals transmitted by the appropriate transmitter for the country in which they are to be used. Depending upon signal strength they may require placement in a location with a relatively unobstructed path to the transmitter and need fair to good atmospheric conditions to successfully update the time. Inexpensive clocks keep track of the time between updates, or in their absence, with a non-disciplined quartz-crystal clock of similar accuracy to a non-radio-controlled quartz timepiece. Some clocks include an indicator to alert users to possible inaccuracy when synchronization has not been successful within the last 24 to 48 hours.

Other broadcasts

Attached to other broadcast stations

Broadcast stations in many countries have carriers precisely synchronized to a standard phase and frequency, such as the BBC Radio 4 longwave service on 198 kHz, and some also transmit sub-audible or even inaudible time-code information, like the Radio France longwave transmitter on 162 kHz. Attached time signal systems generally use audible tones or phase modulation of the carrier wave.

Teletext (TTX)

Digital text pages embedded in television video also provide accurate time. Many modern TV sets and VCRs with TTX decoders can obtain accurate time from Teletext and set the internal clock. However the TTX time can vary up to 5 minutes.[22]

Many digital radio and digital television schemes also include provisions for time-code transmission.

Digital Terrestrial Television

The DVB and ATSC standards have 2 packet types that send time and date information to the receiver. Digital television systems can equal GPS stratum 2 accuracy (with short term clock discipline) and stratum 1 (with long term clock discipline) provided the transmitter site (or network) supports that level of functionality.

VHF FM Radio Data System (RDS)

RDS can send a clock signal with sub-second precision but with an accuracy no greater than 100 ms and with no indication of clock stratum. Not all RDS networks or stations using RDS send accurate time signals. The time stamp format for this technology is Modified Julian Date (MJD) plus UTC hours, UTC minutes and a local time offset.

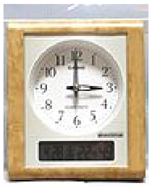
L-band and VHF Digital Audio Broadcasting

DAB systems provide a time signal that has a precision equal to or better than Digital Radio Mondiale (DRM) but like FM RDS do not indicate clock stratum. DAB systems can equal GPS stratum 2 accuracy (short term clock discipline) and stratum 1 (long term clock discipline) provided the transmitter site (or network) supports that level of functionality. The time stamp format for this technology is BCD.

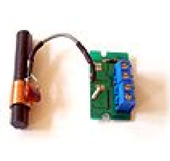
Digital Radio Mondiale (DRM)

DRM is able to send a clock signal, but one not as precise as navigation satellite clock signals. DRM timestamps received via shortwave (or multiple hop mediumwave) can be up to 200 ms off due to path delay. The time stamp format for this technology is BCD.

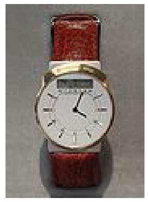
Gallery



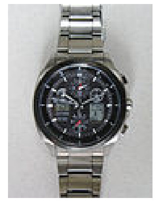
A low frequency (LF) radio clock



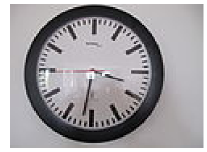
LF time signal receiver



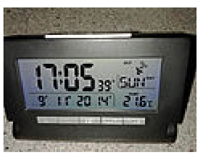
World's first radio clock wrist watch, Junghans Mega (analog model)



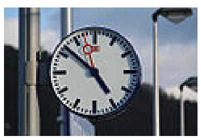
Citizen Attesa Eco-Drive ATV53-3023 analog-digital chronograph with 4 area Radio Controlled reception (North America, Europe, China, Japan)



Radio controlled analog wall clock



Radio controlled alarm clock



The DCF77 time signal is used by organizations like the Deutsche Bahn railway company to synchronize their station clocks

Multiple transmitters

A radio clock receiver may combine multiple time sources to improve its accuracy. This is what is done in satellite navigation systems such as the Global Positioning System. GPS, Galileo and GLONASS satellite navigation systems have one or more caesium, rubidium or hydrogen maser atomic clocks on each satellite, referenced to a clock or clocks on the ground. Dedicated timing receivers can serve as local time standards, with a precision better than 50 ns.[23][24][25][26] The recent revival and enhancement of LORAN, a land-based radio navigation system, will provide another multiple source time distribution system.

GPS clocks

Many modern radio clocks use the Global Positioning System to provide more accurate time than can be obtained from terrestrial radio stations. These *GPS clocks* combine time estimates from multiple satellite atomic clocks with error estimates maintained by a network of ground stations. Due to effects inherent in radio propagation and ionospheric spread and delay, GPS timing requires averaging of these phenomena over several periods. No GPS receiver directly computes time or frequency, rather they use GPS to discipline an oscillator that may range from a quartz crystal in a low-end navigation receiver, through oven-controlled crystal oscillators (OCXO) in specialized units, to atomic oscillators (rubidium) in some receivers used for synchronization in telecommunications. For this reason, these devices are technically referred to as GPS-disciplined oscillators.

GPS units intended primarily for time measurement as opposed to navigation can be set to assume the antenna position is fixed. In this mode, the device will average its position fixes. After approximately a day of operation, it will know its position to within a few meters. Once it has averaged its position, it can determine accurate time even if it can pick up signals from only one or two satellites.

GPS clocks provide the precise time needed for synchrophasor measurement of voltage and current on the commercial power grid to determine the health of the system.[27]

Astronomy timekeeping

Although any satellite navigation receiver that is performing its primary navigational function must have an internal time reference accurate to a small fraction of a second, the displayed time is often not as precise as the internal clock. Most inexpensive navigation receivers have one CPU that is multitasking. The highest-priority task for the CPU is maintaining satellite lock—not updating the display. Multicore CPUs for navigation systems can only be found on high end products.

For serious precision timekeeping, a more specialized GPS device is needed. Some amateur astronomers, most notably those who time grazing lunar occultation events when the moon blocks the light from stars and planets, require the highest precision available for persons working outside large research institutions. The Web site of the International Occultation Timing Association [28] has detailed technical information about precision timekeeping for the amateur astronomer.

Daylight Saving Time

Various of the formats above include a flag indicating the status of daylight saving time (DST) in the home country of the transmitter. This signal is typically used by clocks to adjust the displayed time to meet user expectations.

See also

- Casio Wave Ceptor
- Clock network
- Speaking clock
- Time from NPL
- Time transfer

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External links

- IOTA Observers Manual (http://www.poyntsource.com/IOTAmanual/IOTA_Observers_Manual_all_pages.pdf) This manual from the *International Occultation Timing Association* has very extensive details on methods of accurate time measurement.
- NIST website: WWVB Radio Controlled Clocks (https://www.nist.gov/pml/div688/grp40/radioclocks.cfm)
- NTP Project Development Website (http://ntp.org)

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