Morse code

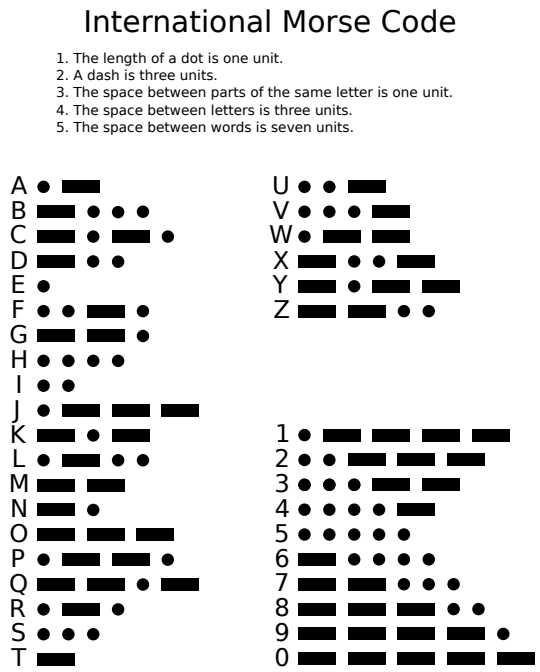


Chart of the Morse code letters and numerals.[1]

Morse code is a method of transmitting text information as a series of on-off tones, lights, or clicks that can be directly understood by a skilled listener or observer without special equipment. It is named for Samuel F. B. Morse, an inventor of the telegraph. The International Morse Code[1] encodes the ISO basic Latin alphabet, some extra Latin letters, the Arabic numerals and a small set of punctuation and procedural signals (prosigns) as standardized sequences of short and long signals called "dots" and "dashes",[1] or "dits" and "dahs", as in amateur radio practice. Because many non-English natural languages use more than the 26 Roman letters, extensions to the Morse alphabet exist for those languages.

Each Morse code symbol represents either a text character (letter or numeral) or a prosign and is represented by a unique sequence of dots and dashes. The duration of a dash is three times the duration of a dot. Each dot or dash is followed by a short silence, equal to the dot duration. The letters of a word are separated by a space equal to three dots (one dash), and the words are separated by a space equal to seven dots. The dot duration is the basic unit of time measurement in code transmission.[1] To increase the speed of the communication, the code was designed so that the length of each character in Morse varies approximately inversely to its frequency of occurrence in English. Thus the most common letter in English, the letter "E", has the shortest code, a single dot.

Morse code is used by some amateur radio operators, although knowledge of and proficiency with it is no longer required for licensing in most countries. Pilots and air traffic controllers usually need only a cursory understanding. Aeronautical navigational aids, such as VORs and NDBs, constantly identify in Morse code. Compared to voice, Morse code is less sensitive to poor signal conditions, yet still comprehensible to humans without a decoding device. Morse is, therefore, a useful alternative to synthesized speech for sending automated data to skilled listeners on voice channels. Many amateur radio repeaters, for example, identify with Morse, even though they are used for voice communications.

SOS, the standard emergency signal, is a Morse code prosign

In an emergency, Morse code can be sent by improvised methods that can be easily "keyed" on and off, making it one of the simplest and most versatile methods of telecommunication. The most common distress signal is SOS or three dots, three dashes, and three dots, internationally recognized by treaty.

1 Development and history

Beginning in 1836, the American artist Samuel F. B. Morse, the American physicist Joseph Henry, and Alfred Vail developed an electrical telegraph system. This system sent pulses of electric current along wires which controlled an electromagnet that was located at the receiving end of the telegraph system. A code was needed to transmit natural language using only these pulses, and the silence between them. Around 1837, Morse, therefore, developed an early forerunner to the modern International Morse code. Around the same time, Carl Friedrich Gauss and Wilhelm Eduard Weber (1833) as well as Carl August von Steinheil (1837) had already used codes with varying word lengths for their telegraphs.

In 1837, William Cooke and Charles Wheatstone in England began using an electrical telegraph that also used electromagnets in its receivers. However, in contrast with any system of making sounds of clicks, their system used pointing needles that rotated above alphabetical charts to

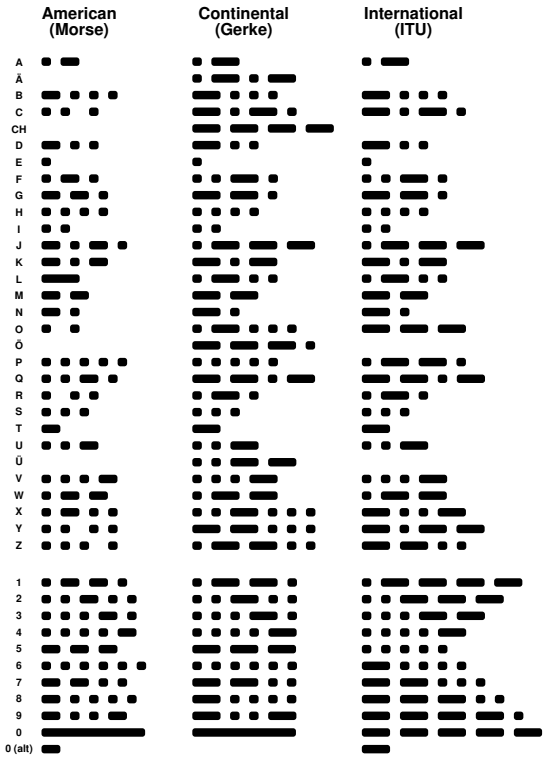
Typical "straight key". This U.S. model J-38, was manufactured in huge quantities during World War II. The signal is "on" when the knob is pressed, and "off" when it is released. Length and timing of the dots and dashes are entirely controlled by the telegraphist.

Morse code receiver, recording on paper tape

indicate the letters that were being sent. In 1841, Cooke and Wheatstone built a telegraph that printed the letters from a wheel of typefaces struck by a hammer. This machine was based on their 1840 telegraph and worked well; however, they failed to find customers for this system and only two examples were ever built.[2]

On the other hand, the three Americans' system for telegraphy, which was first used in about 1844, was designed to make indentations on a paper tape when electric currents were received. Morse's original telegraph receiver used a mechanical clockwork to move a paper tape. When an electrical current was received, an electromagnet engaged an armature that pushed a stylus onto the moving paper tape, making an indentation on the tape. When the current was interrupted, a spring retracted the stylus, and that portion of the moving tape remained unmarked.

The Morse code was developed so that operators could translate the indentations marked on the paper tape into text messages. In his earliest code, Morse had planned to transmit only numerals, and to use a codebook to look up each word according to the number which had been sent. However, the code was soon expanded by Alfred Vail in 1840 to include letters and special characters, so it could be used more generally. Vail estimated the frequency of use of letters in the English language by counting the movable type he found in the type-cases of a local newspaper in Morristown.[3] The shorter marks were called "dots", and the longer ones "dashes", and the letters most commonly used were assigned the shorter sequences of dots and dashes. This code was used since 1844 and became known as *Morse landline code* or *American Morse code*.



Comparison of historical versions of Morse code with the current standard. 1. American Morse code as originally defined. 2. The modified and rationalized version used by Gerke on German railways. 3. The current ITU standard.

In the original Morse telegraphs, the receiver's armature made a clicking noise as it moved in and out of position to mark the paper tape. The telegraph operators soon learned that they could translate the clicks directly into dots and dashes, and write these down by hand, thus making the paper tape unnecessary. When Morse code was adapted to radio communication, the dots and dashes were sent as short and long tone pulses. It was later found that people become more proficient at receiving Morse code when it is taught as a language that is heard, instead of one read from a page.[4]

To reflect the sounds of Morse code receivers, the operators began to vocalize a dot as "dit", and a dash as "dah". Dots which are not the final element of a charac-

ter became vocalized as “di”. For example, the letter “c” was then vocalized as “dah-di-dah-dit”.[5][6] Morse code was sometimes facetiously known as “iddy-umpty”, and a dash as “umpty”, leading to the word "umpteen".[7]

The Morse code, as it is used internationally today, was derived from a much refined proposal which became known as “Hamburg alphabet” by Friedrich Clemens Gerke in 1848. It was adopted by the Deutsch-Österreichischer Telegraphenverein (German-Austrian Telegraph Society) in 1851. This finally led to the International Morse code in 1865.

In the 1890s, Morse code began to be used extensively for early radio communication, before it was possible to transmit voice. In the late 19th and early 20th centuries, most high-speed international communication used Morse code on telegraph lines, undersea cables and radio circuits. In aviation, Morse code in radio systems started to be used on a regular basis in the 1920s. Although previous transmitters were bulky and the spark gap system of transmission was difficult to use, there had been some earlier attempts. In 1910, the US Navy experimented with sending Morse from an airplane.[8] That same year, a radio on the airship *America* had been instrumental in coordinating the rescue of its crew.[9] Zeppelin airships equipped with radio were used for bombing and naval scouting during World War I,[10] and ground-based radio direction finders were used for airship navigation.[10] Allied airships and military aircraft also made some use of radiotelegraphy. However, there was little aeronautical radio in general use during World War I, and in the 1920s, there was no radio system used by such important flights as that of Charles Lindbergh from New York to Paris in 1927. Once he and the *Spirit of St. Louis* were off the ground, Lindbergh was truly alone and incommunicado. On the other hand, when the first airplane flight was made from California to Australia in the 1930s on the *Southern Cross*, one of its four crewmen was its radio operator who communicated with ground stations via radio telegraph.

Beginning in the 1930s, both civilian and military pilots were required to be able to use Morse code, both for use with early communications systems and for identification of navigational beacons which transmitted continuous two- or three-letter identifiers in Morse code. Aeronautical charts show the identifier of each navigational aid next to its location on the map.

Radiotelegraphy using Morse code was vital during World War II, especially in carrying messages between the warships and the naval bases of the belligerents. Long-range ship-to-ship communication was by radio telegraphy, using encrypted messages because the voice radio systems on ships then were quite limited in both their range and their security. Radiotelegraphy was also extensively used by warplanes, especially by long-range patrol planes that were sent out by those navies to scout for enemy warships, cargo ships, and troop ships.

In addition, rapidly moving armies in the field could not have fought effectively without radiotelegraphy because they moved more rapidly than telegraph and telephone lines could be erected. This was seen especially in the blitzkrieg offensives of the Nazi German Wehrmacht in Poland, Belgium, France (in 1940), the Soviet Union, and in North Africa; by the British Army in North Africa, Italy, and the Netherlands; and by the U.S. Army in France and Belgium (in 1944), and in southern Germany in 1945.

Morse code was used as an international standard for maritime distress until 1999 when it was replaced by the Global Maritime Distress Safety System. When the French Navy ceased using Morse code on January 31, 1997, the final message transmitted was “Calling all. This is our last cry before our eternal silence.”[11] In the United States the final commercial Morse code transmission was on July 12, 1999, signing off with Samuel Morse’s original 1844 message, "What hath God wrought", and the prosign “SK”.[12]

As of 2015, the United States Air Force still trains ten people a year in Morse.[13] The United States Coast Guard has ceased all use of Morse code on the radio, and no longer monitors any radio frequencies for Morse code transmissions, including the international medium frequency (MF) distress frequency of 500 kHz.[14] However, the Federal Communications Commission still grants commercial radiotelegraph operator licenses to applicants who pass its code and written tests.[15] Licensees have reactivated the old California coastal Morse station KPH and regularly transmit from the site under either this Call sign or as KSM. Similarly, a few US Museum ship stations are operated by Morse enthusiasts.[16]

2 User proficiency

A commercially manufactured iambic paddle used in conjunction with an electronic keyer to generate high-speed Morse code, the timing of which is controlled by the electronic keyer. Manipulation of dual-lever paddles is similar to the Vibroplex, but pressing the right paddle generates a series of dahs*, and squeezing the paddles produces dit-dah-dit-dah sequence. The actions are reversed for left-handed operators.*

Morse code speed is measured in words per minute (wpm) or characters per minute (cpm). Characters have differing lengths because they contain differing numbers of dots and dashes. Consequently, words also have different lengths in terms of dot duration, even when they contain the same number of characters. For this reason, a standard word is helpful to measure operator transmission speed. “PARIS” and “CODEX” are two such standard words.[17] Operators skilled in Morse code can often understand (“copy”) code in their heads at rates in excess of 40 wpm.

In addition to knowing, understanding, and being able to copy the standard written alpha-numeric and punctuation characters or symbols at high speeds, skilled high speed operators must also be fully knowledgeable of all of the special unwritten Morse code symbols for the standard Prosigns for Morse code and the meanings of these special procedural signals in standard Morse code communications protocol.

International contests in code copying are still occasionally held. In July 1939 at a contest in Asheville, North Carolina in the United States Ted R. McElroy set a still-standing record for Morse copying, 75.2 wpm.[18] William Pierpont N0HFF also notes that some operators may have passed 100 wpm.[18] By this time, they are “hearing” phrases and sentences rather than words. The fastest speed ever sent by a straight key was achieved in 1942 by Harry Turner W9YZE (d. 1992) who reached 35 wpm in a demonstration at a U.S. Army base. To accurately compare code copying speed records of different eras it is useful to keep in mind that different standard words (50 dot durations versus 60 dot durations) and different interword gaps (5 dot durations versus 7 dot durations) may have been used when determining such speed records. For example, speeds run with the CODEX standard word and the PARIS standard may differ by up to 20%.

Today among amateur operators there are several organizations that recognize high-speed code ability, one group consisting of those who can copy Morse at 60 wpm.[19] Also, Certificates of Code Proficiency are issued by several amateur radio societies, including the American Radio Relay League. Their basic award starts at 10 wpm with endorsements as high as 40 wpm, and are available to anyone who can copy the transmitted text. Members of the Boy Scouts of America may put a Morse interpreter’s strip on their uniforms if they meet the standards for translating code at 5 wpm.

3 International Morse Code

Morse code has been in use for more than 160 years—longer than any other electrical coding system. What is called Morse code today is actually somewhat different from what was originally developed by Vail and Morse. The Modern International Morse code, or *continental code*, was created by Friedrich Clemens Gerke in 1848 and initially used for telegraphy between Hamburg and Cuxhaven in Germany. Gerke changed nearly half of the alphabet and all of the numerals, providing the foundation for the modern form of the code. After some minor changes, International Morse Code was standardized at the International Telegraphy Congress in 1865 in Paris and was later made the standard by the International Telecommunication Union (ITU). Morse’s original code specification, largely limited to use in the United States and Canada, became known as American Morse code or *railroad code*. American Morse code is now seldom used except in historical re-enactments.

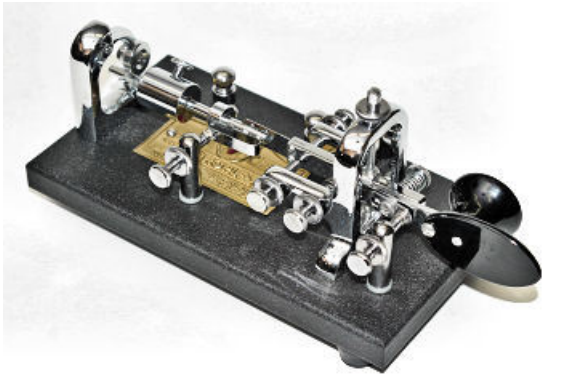
3.1 Aviation

In aviation, instrument pilots use radio navigation aids. To ensure that the stations the pilots are using are serviceable, the stations all transmit a short set of identification letters (usually a two-to-five-letter version of the station name) in Morse code. Station identification letters are shown on air navigation charts. For example, the VOR based at Manchester Airport in England is abbreviated as “MCT”, and MCT in Morse code is transmitted on its radio frequency. In some countries, during periods of maintenance, the facility may radiate a T-E-S-T code (▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬) or the code may be removed which tells pilots and navigators that the station is unreliable. In Canada, the identification is removed entirely to signify the navigation aid is not to be used.[20][21] In the aviation service, Morse is typically sent at a very slow speed of about 5 words per minute. In the U.S., pilots do not actually have to know Morse to identify the transmitter because the dot/dash sequence is written out next to the transmitter’s symbol on aeronautical charts. Some modern navigation receivers automatically translate the code into displayed letters.

3.2 Amateur radio

International Morse code today is most popular among amateur radio operators, where it is used as the pattern to key a transmitter on and off in the radio communications mode commonly referred to as "continuous wave" or “CW” to distinguish it from spark transmissions, not because the transmission was continuous. Other keying methods are available in radio telegraphy, such as frequency shift keying.

The original amateur radio operators used Morse code exclusively since voice-capable radio transmitters did not become commonly available until around 1920. Until 2003, the International Telecommunication Union mandated Morse code proficiency as part of the amateur radio licensing procedure worldwide. However, the World Radiocommunication Conference of 2003 made the Morse



Vibroplex brand semiautomatic key (generically called a "bug"). The paddle, when pressed to the right by the thumb, generates a series of dits*, the length and timing of which are controlled by a sliding weight toward the rear of the unit. When pressed to the left by the knuckle of the index finger, the paddle generates a single* dah*, the length of which is controlled by the operator. Multiple* dahs *require multiple presses. Left-handed operators use a key built as a mirror image of this one.*

code requirement for amateur radio licensing optional.[22] Many countries subsequently removed the Morse requirement from their licence requirements.[23]

Until 1991, a demonstration of the ability to send and receive Morse code at a minimum of five words per minute (wpm) was required to receive an amateur radio license for use in the United States from the Federal Communications Commission. Demonstration of this ability was still required for the privilege to use the HF bands. Until 2000, proficiency at the 20 wpm level was required to receive the highest level of amateur license (Amateur Extra Class); effective April 15, 2000, the FCC reduced the Extra Class requirement to five wpm.[24] Finally, effective on February 23, 2007, the FCC eliminated the Morse code proficiency requirements from all amateur radio licenses.

While voice and data transmissions are limited to specific amateur radio bands under U.S. rules, Morse code is permitted on all amateur bands—LF, MF, HF, VHF, and UHF. In some countries, certain portions of the amateur radio bands are reserved for transmission of Morse code signals only.

The relatively limited speed at which Morse code can be sent led to the development of an extensive number of abbreviations to speed communication. These include prosigns, Q codes, and a set of Morse code abbreviations for typical message components. For example, CQ is broadcast to be interpreted as "seek you" (I'd like to converse with anyone who can hear my signal). OM (old man), YL (young lady) and XYL ("ex-YL" – wife) are common abbreviations. YL or OM is used by an operator when referring to the other operator, XYL or OM is used by an operator when referring to his or her spouse. QTH is "location" ("My QTH" is "My location"). The use of abbreviations for common terms permits conversation even when the operators speak different languages.

Although the traditional telegraph key (straight key) is still used by some amateurs, the use of mechanical semi-automatic keyers (known as "bugs") and of fully automatic electronic keyers is prevalent today. Software is also frequently employed to produce and decode Morse code radio signals.

3.3 Other uses

A U.S. Navy signalman sends Morse code signals in 2005.

Through May 2013, the First, Second, and Third Class (commercial) Radiotelegraph Licenses using code tests based upon the CODEX standard word were still being issued in the United States by the Federal Communications Commission. The First Class license required 20 WPM code group and 25 WPM text code proficiency, the others 16 WPM code group test (five letter blocks sent as simulation of receiving encrypted text) and 20 WPM code text (plain language) test. It was also necessary to pass written tests on operating practice and electronics theory. A unique additional demand for the First Class was a requirement of a year of experience for operators of shipboard and coast stations using Morse. This allowed the holder to be chief operator on board a passenger ship. However, since 1999 the use of satellite and very high-frequency maritime communications systems (GMDSS) has made them obsolete. (By that point meeting experience requirement for the First was very difficult.) Currently, only one class of license, the Radiotelegraph Operator Certificate, is issued. This is granted either when the tests are passed or as the Second and First are renewed and become this lifetime license. For new applicants, it

requires passing a written examination on electronic theory, as well as 16 WPM code and 20 WPM text tests. However, the code exams are currently waived for holders of Amateur Extra Class licenses who obtained their operating privileges under the old 20 WPM test requirement.

Radio navigation aids such as VORs and NDBs for aeronautical use broadcast identifying information in the form of Morse Code, though many VOR stations now also provide voice identification.[25] Warships, including those of the U.S. Navy, have long used signal lamps to exchange messages in Morse code. Modern use continues, in part, as a way to communicate while maintaining radio silence.

ATIS (Automatic Transmitter Identification System) uses Morse code to identify uplink sources of analog satellite transmissions.

3.4 Applications for the general public

Representation of SOS-Morse code.

An important application is signalling for help through SOS, "▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬". This can be sent many ways: keying a radio on and off, flashing a mirror, toggling a flashlight, and similar methods. SOS is not three separate characters, rather, it is a prosign SOS, and is keyed without gaps between characters.[26]

Some Nokia mobile phones offer an option to alert the user of an incoming text message with the Morse tone "▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬" (representing SMS or Short Message Service). In addition, applications are now available for mobile phones that enable short messages to be input in Morse Code.[27]

3.5 Morse code as an assistive technology

Morse code has been employed as an assistive technology, helping people with a variety of disabilities to communicate. Morse can be sent by persons with severe motion disabilities, as long as they have some minimal motor control. An original solution to the problem that caretakers have to learn to decode has been an electronic typewriter with the codes written on the keys. Codes were sung by users; see the voice typewriter employing morse or votem, Newell and Nabarro, 1968.

Morse code can also be translated by computer and used in a speaking communication aid. In some cases, this means alternately blowing into and sucking on a plastic tube ("sip-and-puff" interface). An important advantage of Morse code over row column scanning is that once learned, it does not require looking at a display. Also, it appears faster than scanning.

People with severe motion disabilities in addition to sensory disabilities (e.g. people who are also deaf or blind) can receive Morse through a skin buzzer. .

In one case reported in the radio amateur magazine *QST*,[28] an old shipboard radio operator who had a stroke and lost the ability to speak or write could communicate with his physician (a radio amateur) by blinking his eyes in Morse. Another example occurred in 1966 when prisoner of war Jeremiah Denton, brought on television by his North Vietnamese captors, Morse-blinked the word *TORTURE*. In these two cases, interpreters were available to understand those series of eye-blinks.

4 Representation, timing, and speeds

International Morse code is composed of five elements:[1]

1. short mark, dot or "dit" (▬▬▬): "dot duration" is one time unit long
2. longer mark, dash or "dah" (▬▬▬▬▬): three time units long
3. inter-element gap between the dots and dashes within a character: one dot duration or one unit long
4. short gap (between letters): three time units long
5. medium gap (between words): seven time units long

4.1 Transmission

Morse code can be transmitted in a number of ways: originally as electrical pulses along a telegraph wire, but also as an audio tone, a radio signal with short and long tones, or as a mechanical, audible, or visual signal (e.g. a flashing light) using devices like an Aldis lamp or a heliograph, a common flashlight, or even a car horn. Some mine rescues have used pulling on a rope - a short pull for a dot and a long pull for a dash.

Morse code is transmitted using just two states (on and off). Historians have called it the first digital code. Morse code may be represented as a binary code, and that is what telegraph operators do when transmitting messages. Working from the above ITU definition and further defining a bit as a dot time, a Morse code sequence may be made from a combination of the following five-bit strings:

1. short mark, dot or "dit" (▬▬▬): 1
2. longer mark, dash or "dah" (▬▬▬▬▬): 111

3. intra-character gap (between the dots and dashes within a character): 0
4. short gap (between letters): 000
5. medium gap (between words): 0000000

Note that the marks and gaps alternate: dots and dashes are always separated by one of the gaps, and that the gaps are always separated by a dot or a dash.

Morse messages are generally transmitted by a hand-operated device such as a telegraph key, so there are variations introduced by the skill of the sender and receiver — more experienced operators can send and receive at faster speeds. In addition, individual operators differ slightly, for example, using slightly longer or shorter dashes or gaps, perhaps only for particular characters. This is called their "fist", and experienced operators can recognize specific individuals by it alone. A good operator who sends clearly and is easy to copy is said to have a "good fist". A "poor fist" is a characteristic of sloppy or hard to copy Morse code.

4.2 Timing

Below is an illustration of timing conventions. The phrase "MORSE CODE", in Morse code format, would normally be written something like this, where – represents dahs and · represents dits:

–– ––– ·–· ··· · –·–· ––– –·· · M O R S E C O D E

Next is the exact conventional timing for this phrase, with = representing "signal on", and . representing "signal off", each for the time length of exactly one dit:

1 2 3 4 5 6 7 8
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789.
M------ O---------- R------ S---
- E C---------- O---------- D------ E
===.===...===.===.===...=.===.=...=.=.=...=.....===.=.===.=...===.===.===...===.=.=...=
^ ^ ^ ^ ^ | dah dit | | symbol space letter space word space

4.3 Spoken representation

Morse code is often spoken or written with "dah" for dashes, "dit" for dots located at the end of a character, and "di" for dots located at the beginning or internally within the character. Thus, the following Morse code sequence:

M O R S E C O D E –– ––– ·–· ··· · (space) –·–· ––– –·· ·

is orally:

Dah-dah dah-dah-dah di-dah-dit di-di-dit dit, Dah-di-dah-dit dah-dah-dah dah-di-dit dit.

There is little point in learning to read *written* Morse as above; rather, the *sounds* of all of the letters and symbols need to be learned, for both sending and receiving.

4.4 Speed in words per minute

All Morse code elements depend on the dot length. A dash is the length of 3 dots, and spacings are specified in number of dot lengths. An unambiguous method of specifying the transmission speed is to specify the dot duration as, for example, 50 milliseconds.

Specifying the dot duration is, however, not the common practice. Usually, speeds are stated in words per minute. That introduces ambiguity because words have different numbers of characters, and characters have different dot lengths. It is not immediately clear how a specific word rate determines the dot duration in milliseconds.

Some method to standardize the transformation of a word rate to a dot duration is useful. A simple way to do this is to choose a dot duration that would send a typical word the desired number of times in one minute. If, for example, the operator wanted a character speed of 13 words per minute, the operator would choose a dot rate that would send the typical word 13 times in exactly one minute.

The typical word thus determines the dot length. It is common to assume that a word is 5 characters long. There are two common typical words: "PARIS" and "CODEX". PARIS mimics a word rate that is typical of natural language words and reflects the benefits of Morse code's shorter code durations for common characters such as "e" and "t". CODEX offers a word rate that is typical of 5-letter code groups (sequences of random letters). Using the word PARIS as a standard, the number of dot units is 50 and a simple calculation shows that the dot length at 20 words per minute is 60 milliseconds. Using the word CODEX with 60 dot units, the dot length at 20 words per minute is 50 milliseconds.

Because Morse code is usually sent by hand, it is unlikely that an operator could be that precise with the dot length, and the individual characteristics and preferences of the operators usually override the standards.

For commercial radiotelegraph licenses in the United States, the Federal Communications Commission specifies tests for Morse code proficiency in words per minute and in code groups per minute.[29] The Commission specifies that a word is 5-characters long. The Commission specifies Morse code test elements at 16 code groups per minute, 20 words per minute, 20 code groups per minute, and 25 words per minute.[30] The word per minute rate would be close to the PARIS standard, and the code groups per minute would be close to the CODEX standard.

While the Federal Communications Commission no longer requires Morse code for amateur radio licenses,

the old requirements were similar to the requirements for commercial radiotelegraph licenses.[31]

A difference between amateur radio licenses and commercial radiotelegraph licenses is that commercial operators must be able to receive code groups of random characters along with plain language text. For each class of license, the code group speed requirement is slower than the plain language text requirement. For example, for the Radiotelegraph Operator License, the examinee must pass a 20 word per minute plain text test and a 16 word per minute code group test.[15]

Based upon a 50 dot duration standard word such as PARIS, the time for one dot duration or one unit can be computed by the formula:

$$T = 1200 / W$$

Where: T is the unit time, or dot duration in milliseconds, and W is the speed in wpm.

High-speed telegraphy contests are held; according to the *Guinness Book of Records* in June 2005 at the International Amateur Radio Union's 6th World Championship in High Speed Telegraphy in Primorsko, Bulgaria, Andrei Bindasov of Belarus transmitted 230 morse code marks of mixed text in one minute.[32]

4.5 Farnsworth speed

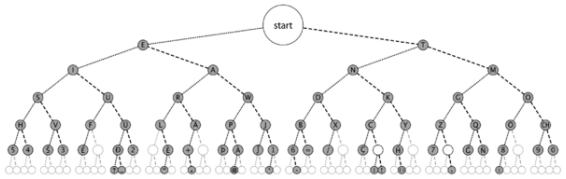
Sometimes, especially while teaching Morse code, the timing rules above are changed so two different speeds are used: a character speed and a text speed. The character speed is how fast each individual letter is sent. The text speed is how fast the entire message is sent. For example, individual characters may be sent at a 13 words-per-minute rate, but the intercharacter and interword gaps may be lengthened so the word rate is only 5 words per minute.

Using different character and text speeds is, in fact, a common practice, and is used in the Farnsworth method of learning Morse code.

4.6 Alternative display of common characters in International Morse code

See also: Huffman coding

Some methods of teaching Morse code use a dichotomic search table.



Graphical representation of the dichotomic search table. The graph branches left for each dot and right for each dash until the character representation is exhausted.

4.7 Link budget issues

Morse Code cannot be treated as a classical radioteletype (RTTY) signal when it comes to calculating a link margin or a link budget for the simple reason of it possessing variable length dots and dashes as well as variant timing between letters and words. For the purposes of Information Theory and Channel Coding comparisons, the word *PARIS* is used to determine Morse Code's properties because it has an even number of dots and dashes.

Morse Code, when transmitted essentially, creates an AM signal (even in on/off keying mode), assumptions about signal can be made with respect to similarly timed RTTY signalling. Because Morse code transmissions employ an on-off keyed radio signal, it requires less complex transmission equipment than other forms of radio communication.

Morse code also requires less signal bandwidth than voice communication, typically 100–150 Hz, compared to the roughly 2400 Hz used by single-sideband voice, although at a lower data rate.

Morse code is usually heard at the receiver as a medium-pitched on/off audio tone (600–1000 Hz), so transmissions are easier to copy than voice through the noise on congested frequencies, and it can be used in very high noise / low signal environments. The transmitted power is concentrated into a limited bandwidth so narrow receiver filters can be used to suppress interference from adjacent frequencies. The audio tone is usually created by use of a beat frequency oscillator.

The narrow signal bandwidth also takes advantage of the natural aural selectivity of the human brain, further enhancing weak signal readability. This efficiency makes CW extremely useful for DX (distance) transmissions, as well as for low-power transmissions (commonly called "QRP operation", from the Q-code for “reduce power”).

The ARRL has a readability standard for robot encoders called ARRL Farnsworth Spacing [33] that is supposed to have higher readability for both robot and human decoders. Some programs like WinMorse [34] have implemented the standard.

5 Learning methods

People learning Morse code using the **Farnsworth method** are taught to send and receive letters and other symbols at their full target speed, that is with normal rel-

ative timing of the dots, dashes, and spaces within each symbol for that speed. The Farnsworth method is named for Donald R. “Russ” Farnsworth, also known by his call sign, W6TTB. However, initially exaggerated spaces between symbols and words are used, to give “thinking time” to make the sound “shape” of the letters and symbols easier to learn. The spacing can then be reduced with practice and familiarity.

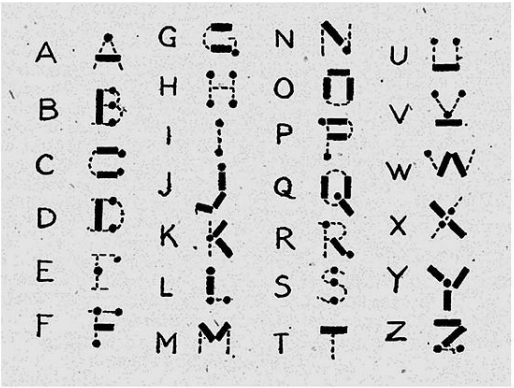
Another popular teaching method is the **Koch method**, named after German psychologist Ludwig Koch, which uses the full target speed from the outset but begins with just two characters. Once strings containing those two characters can be copied with 90% accuracy, an additional character is added, and so on until the full character set is mastered.

In North America, many thousands of individuals have increased their code recognition speed (after initial memorization of the characters) by listening to the regularly scheduled code practice transmissions broadcast by W1AW, the American Radio Relay League’s headquarters station.

5.1 Mnemonics

Main article: Morse code mnemonics

Visual mnemonic charts have been devised over the ages. Baden-Powell included one in the Girl Guides handbook[35] in 1918.



Scout movement founder Baden-Powell’s mnemonic chart from 1918

In the United Kingdom, many people learned the Morse code by means of a series of words or phrases that have the same rhythm as a Morse character. For instance, “Q” in Morse is dah-dah-di-dah, which can be memorized by the phrase “God save the Queen”, and the Morse for “F” is di-di-dah-dit, which can be memorized as “Did she like it.”

A well-known Morse code rhythm from the Second World War period derives from Beethoven's Fifth Symphony, the opening phrase of which was regularly played at the beginning of BBC broadcasts. The timing of the notes corresponds to the Morse for “V"; di-di-di-dah and stood for “V for Victory” (as well as the Roman numeral for the number five).[36][37]

6 Letters, numbers, punctuation, prosigns for Morse code and non-English variants

6.1 Prosigns

Main article: Prosigns for Morse code

Prosigns for Morse code are special (usually) unwritten procedural signals or symbols that are used to indicate changes in communications protocol status or white space text formatting actions.

6.2 Symbol representations

The symbols !, $ and & are not defined inside the ITU recommendation on Morse code, but conventions for them exist. The @ symbol was formally added in 2004.

Exclamation mark

There is no standard representation for the exclamation mark (!), although the KW digraph (▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬) was proposed in the 1980s by the Heathkit Company (a vendor of assembly kits for amateur radio equipment).

While Morse code translation software prefers the Heathkit version, on-air use is not yet universal as some amateur radio operators in North America and the Caribbean continue to prefer the older MN digraph (▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬) carried over from American landline telegraphy code.

Currency symbols

- The ITU has never codified formal Morse Code representations for currencies as the ISO 4217 Currency Codes are preferred for transmission.
- The $ sign code was represented in the Phillips Code, a huge collection of abbreviations used on land line telegraphy, as SX.

Ampersand

- The representation of the & sign given above, often shown as AS, is also the Morse prosign for **wait**. In addition, the American landline representation of an ampersand was similar to “ES”

([redacted]) and hams have carried over this usage as a synonym for “and” (WX HR COLD ES RAINY, “the weather here is cold & rainy”).

Keyboard AT @

- On May 24, 2004 — the 160th anniversary of the first public Morse telegraph transmission — the Radiocommunication Bureau of the International Telecommunication Union (ITU-R) formally added the @ ("commercial at" or “commat”) character to the official Morse character set, using the sequence denoted by the AC digraph ([redacted]).
- This sequence was reportedly chosen to represent “A[T] C[OMMERCIAL]" or a letter “a” inside a swirl represented by a “C”.[38] The new character facilitates sending email addresses by Morse code and is notable since it is the first official addition to the Morse set of characters since World War I.

6.3 Non-Latin extensions

Main article: Other alphabets in Morse code

For Chinese, Chinese telegraph code is used to map Chinese characters to four-digit codes and send these digits out using standard Morse code. Korean Morse code uses the SKATS mapping, originally developed to allow Korean to be typed on western typewriters. SKATS maps hangul characters to arbitrary letters of the Latin script and has no relationship to pronunciation in Korean. For Russian and Bulgarian, Russian Morse code is used to map the Cyrillic characters to four-element codes. Many of the characters are encoded the same way (A, O, E, I, T, M, N, R, K, etc.). Bulgarian alphabet contains 30 characters, which exactly match all possible combinations of 1, 2, 3, and 4 dots and dashes. Russian requires 1 extra character, "Ы" which is encoded with 5 elements.

6.4 Unusual variants

During early World War I (1914–1916), Germany briefly experimented with 'dotty' and 'dashy' Morse, in essence adding a dot or a dash at the end of each Morse symbol. Each one was quickly broken by Allied SIGINT, and standard Morse was restored by Spring 1916. Only a small percentage of Western Front (North Atlantic and Mediterranean Sea) traffic was in 'dotty' or 'dashy' Morse during the entire war. In popular culture, this is mostly remembered in the book *The Codebreakers* by Kahn and in the national archives of the UK and Australia (whose SIGINT operators copied most of this Morse variant). Kahn’s cited sources come from the popular press and wireless magazines of the time.[39]

Other forms of 'Fractional Morse' or 'Fractionated Morse' have emerged.[40]

7 Decoding software

Decoding software for Morse code ranges from software-defined wide-band radio receivers coupled to the Reverse Beacon Network,[41] which decodes signals and detects CQ messages on ham bands, to smartphone applications.[42]

8 See also

- ACP-131
- CW Operators’ Club
- Guglielmo Marconi
- High-speed telegraphy
- Hog morse
- Instructograph
- Morse code abbreviations
- Morse code mnemonics
- NATO phonetic alphabet
- Tap code
- Wabun code
- Wireless telegraphy
- Theodore Roosevelt McElroy

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[29] Title 47 Code of Federal Regulations §13.207(c) and Title 47 Code of Federal Regulations §13.209(d)

[30] 47 CFR §13.203(b)

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10 External links

- Morse code at DMOZ
- "Everyone Knows Morse". *TV Tropes*.. Includes a list of uses and appearances of Morse Code in movies, television episodes, and other popular culture.
- Morse Code resources
- Morse code MP3 practice files. 200 hours of at increasing speeds plus an ASCII-to-CW file generator program.
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