18 Morse Code

In the UK and an increasing number of countries, it is no longer necessary to pass a Morse test in order to gain access to the bands below 30MHz. This might be thought to lead to an overall decline in Morse activity, but there has been a welcome influx of new operators trying their hand at Morse, at their own speed, and without the daunting hurdle of a formal test to overcome.

The IARU band plans reserve the bottom portion of most bands for Morse, with the faster ('QRQ') signals generally occupying the bottom 30kHz of each HF band, and slower stations higher up. By agreement within IARU, the 10MHz band is not to be used for SSB or other wide bandwidth modes, and is almost exclusively given over to Morse code.

Radio amateurs use the terms 'Morse' and 'CW' interchangeably. This may seem strange, since CW stands for Continuous Wave, whereas Morse code is anything but continuous. However, almost all amateur Morse is sent by on-off keying of a continuous carrier so CW is widely used as a synonym for Morse.

Operators come to use Morse for a variety of reasons, and compulsion is no longer one of them. **Table 18.1** lists ten arguments in favour of the use of Morse:

History

Morse code isn't a code, and it wasn't invented by Morse. Strictly speaking, a scheme in which each letter is represented by a symbol (combination of dots and dashes in this case) is referred to as a cypher, not a code, and the basic idea of using dots and dashes was invented by Samuel Morse's assistant, Alfred Vail.

Starting in 1837 and building on the work of Joseph Henry, the artist Samuel Finley Breese Morse worked to develop a practical electric telegraph. Morse's idea was that common words in a message would be represented by numbers, and these numbers would be transmitted as a series of dots. At the receiving end, the dots would be marked by the equipment on paper tape. The operator would then have to decode the dots to work out which numbers were being sent, and look up the number combinations in a dictionary to find the word. Less common words would be spelled out, with numbers again representing letters. At about the same time in England, Cooke and Wheatstone were also working on the development of an electric telegraph.

While Morse was working on his system in New York City, his partner Alfred Vail thirty miles away in Morristown, New Jersey made numerous improvements to Morse's equipment. It was Vail's idea that instead of using a series of dots for numbers, the code could be made up of combinations of dots, dashes and spaces to represent letters directly. In this way a message could be spelled out without the need to look up code numbers in a book.

Samuel Morse was an incurable self-publicist and failed to give Vail credit in his lifetime as the true inventor of the code that bears Morse's name. When developing his code, Vail visited a local printer in Morristown to find out which letters occurred most frequently in English text, and he assigned the shortest combinations of dots and dashes to these letters. At the time of the first public demonstrations of Morse code, the code was made up of four elements in addition to the standard space: dot, dash, long dash and long space. The code underwent further changes but remained in use as American Morse code until well into the 20th century.

Advantages of using Morse code

1. **Simple equipment.** It is possible to build a simple CW transmitter using fewer than a dozen parts, and a direct conversion receiver can give acceptable performance on CW. The art of 'homebrewing' is alive and well, and building a CW transmitter and/or receiver can get an amateur onto the air on CW very easily and cheaply.

2. **International.** It is easy to get around the language barrier by the use of abbreviations such as *QTH* and *73*, so that two amateurs can have an elementary QSO without knowing each other's language, and without accent or phonetic problems that may arise on phone.

3. **Silent operation.** Wearing headphones and using a straight key or bug, it is possible to operate CW silently, at night time without disturbing others sleeping in the house. Similarly, holiday operation on CW from a hotel can be done in 'stealth' mode.

4. **Morse gets through.** Cross-mode contacts aren't very common, perhaps because they're not valid for most awards, but when struggling to copy a weak phone station on a crowded band it's surprising how often a switch to CW will enable the contact to be completed.

5. **Spectrum efficiency.** The minimum bandwidth needed to copy an SSB signal is about 1.8kHz, and to sound natural the requirement is more like 2.5kHz. On the other hand IF filters for CW operation are typically only 500Hz wide, and if necessary CW can be copied through filters of 100Hz or less. Put simply, at least five times as many CW contacts can fit in the bandwidth required for SSB.

6. **Less breakthrough.** Those who operate both modes know that breakthrough problems are worse on SSB than CW. It is always better to try and resolve any TVI or RFI problem but if this is not possible it may be that switching to CW enables operation to continue, when it is impossible on phone. And if power has to be reduced, CW comes into its own.

7. **More competitive.** The difference between 'big gun' and 'little pistol' seems to be accentuated on phone. The low power or antenna-limited operator may struggle for contacts on phone, whereas CW is a great leveller.

8. **Morse is a skill.** It's wrong to say that phone operation doesn't require skill, but the basic skill required is that of speech, which just about everyone has. On the other hand, a new skill has to be learned in order to be able to communicate using CW, and the sense of achievement can be considerable.

9. **Automation.** There are computer programs which make it possible to automate the transmission and reception of Morse code. This makes it possible under some conditions to engage in CW contacts without knowing the code, but this would be to miss the whole point: it would be much better to use a more efficient automated mode such as PSK31. In any case, a good human operator can easily outperform most computer techniques when copying a CW signal on a channel with even a moderate amount of interference or fading.

10. **Morse is easy.** The general public thinks that Morse is a language, and at special event stations Morse operation always proves fascinating to visitors. All that is needed to acquire Morse skills is to learn the symbols for 26 letters, ten numbers and a few special characters. This is a very great deal easier than learning a foreign language complete with all its grammar and vocabulary.

Table 18.1: Why operating using Morse is still popular, despite learning the code no longer being compulsory

Alphabet and numerals

A	di-dah
B	dah-di-di-dit
C	dah-di-dah-dit
D	dah-di-dit
E	dit
F	di-di-dah-dit
G	dah-dah-dit
H	di-di-di-dit
I	di-dit
J	di-dah-dah-dah
K	dah-di-dah
L	di-dah-di-dit
M	dah-dah
N	dah-dit
O	dah-dah-dah
P	di-dah-dah-dit
Q	dah-dah-di-dah
R	di-dah-dit
S	di-di-dit
T	dah
U	di-di-dah
V	di-di-di-dah
W	di-dah-dah
X	dah-di-di-dah
Y	dah-di-dah-dah
Z	dah-dah-di-dit

Accented letters

à, á, â	di-dah-dah-di-dah
ä	di-dah-di-dah
ç	dah-di-dah-di-dit
ch	dah-dah-dah-dah
è, é	di-di-dah-di-dit
ê	dah-di-di-dah-dit
ñ	dah-dah-di-dah-dah
ö, ó, ô	dah-dah-dah-dit
ü, û	di-di-dah-dah

Abbreviated numerals

1	di-dah 6 dah-di-di-di-dit
2	di-di-dah 7 dah-di-di-dit
3	di-di-di-dah 8 dah-di-dit
4	di-di-di-di-dah 9 dah-dit
5	di-di-di-di-dit 0 daaah (long dash)
1	di-dah-dah-dah-dah
2	di-di-dah-dah-dah
3	di-di-di-dah-dah
4	di-di-di-di-dah
5	di-di-di-di-di
6	dah-di-di-di-dit
7	dah-dah-di-di-dit
8	dah-dah-dah-di-dit
9	dah-dah-dah-dah-dit
0	dah-dah-dah-dah-dah

Punctuation and other codes

Full stop (.)	di-dah-di-dah-di-dah
Comma (,)	dah-dah-di-di-dah-dah
Colon (:)	dah-dah-dah-di-di-dit
Question mark (?)	di-di-dah-dah-di-dit
Apostrophe (')	di-dah-dah-dah-dah-dit
Hyphen or dash (-)	dah-di-di-di-di-dah
Fraction or slash (/)	dah-di-di-dah-dit
Brackets - open [(]	dah-di-dah-dah-dit
- close [)]	dah-di-dah-dah-di-dah
Double hyphen (=)	dah-di-di-di-dah
Quotation marks (")	di-dah-di-di-dah-dit
Error	di-di-di-di-di-di-di-dit
Message starts (CT)	dah-di-dah-di-dah
Message ends (AR)	di-dah-di-dah-dit
End of work (VA)	di-di-di-dah-di-dah
Wait (AS)	di-dah-di-di-dit
Understood (SN)	di-di-di-dah-dit
The @ in e-mails	di-dah-dah-di-dah-dit

Spacing and length of signals

1 A dash is equal to three dots.
2 The space between the signals which form the same letter is equal to one dot.
3 The space between two letters is equal to three dots.
4 The space between two words is equal to seven dots.

Table 18.2: The Morse code and its sound equivalents

The electric telegraph and Morse code started to be used in Europe in the mid to late 1840s. A German, Frederick Gerke, addressed the problem of distinguishing between standard and long dashes, and standard and long spaces, by reducing the code to just the elements of dot and dash that we are familiar with today. More changes were made and in 1865 the 'continental' or 'international' Morse code came into being, in very much the form that exists today. Small changes have been made to the code since then, the most recent being the adoption in 2004 of a new Morse code symbol for the '@' used in Internet addresses.

Both Vail and Morse intended that Morse characters should be printed onto paper tape and read as dots and dashes from there, but it soon became apparent that operators were learning to decode from the clicks of the machinery marking the tape. This led to the development of the sounder and now whenever Morse is written down it is always written down directly as letters, never as individual dots and dashes. A modern exception to this is QRSS, or extremely slow Morse decoded using a FFT program (as used on 136kHz and for very low power experiments) which is displayed as dots and dashes on a computer screen and decoded by eye.

THE CODE

Although Morse is composed of dots and dashes it is better to think of the elements as 'dits' and 'dahs'. These are in the correct proportions so that saying 'di-dah-di-dit' out loud is the correct representation of the letter 'L'. Spacing and rhythm are essential to good Morse code. The inter-element space is the same duration as a dit length, while the length of a dah is three times the dit length. The space between letters of a word is three dit lengths and the space between words is seven dits.

As well as the letters and numbers, **Table 18.2** lists commonly used punctuation and procedural symbols ('prosigns') in common use on the amateur bands.

SPEED

For many years it was necessary in order to gain an amateur licence, to pass a Morse test at 12 words per. minute (WPM). In practice this is the minimum speed that is generally heard on the amateur bands. A word is defined as 50 dit lengths, and this is referred to as the Paris standard since the word 'PARIS', including the seven dit lengths at the end of the word, is exactly the right length. By coincidence the word 'MORSE' is also exactly the right length.

A simple method of measuring speed is repeatedly to send PARIS, including the correct inter-word gap, and count how many are sent in a minute. At a speed of 12WPM the word can be sent just once in five seconds. Another method of measurement which is simple to do but overstates the speed by 4 percent is to count the number of dashes in a five second period.

LEARNING MORSE CODE

A later chapter in this manual shows the extent to which the personal computer has become an integral part of the radio amateur's shack. There is a method of learning Morse code which goes back to the 1930s but has come into its own in the age of the computer. That is the Koch method.

Ludwig Koch was a German psychologist who carried out a systematic study of skilled Morse operators, and then conducted a series of trials to find the most efficient way of teaching Morse to new students. Existing methods at that time were based on learning the letters either visually, or audibly at a slow speed and then increasing speed by constant practice. This approach to learning Morse is fundamentally flawed. Learning all the letters at slow speed requires a conscious mental translation from the combination of dits and dahs to the corresponding letter. After all letters have been memorised, the student hears a combination of

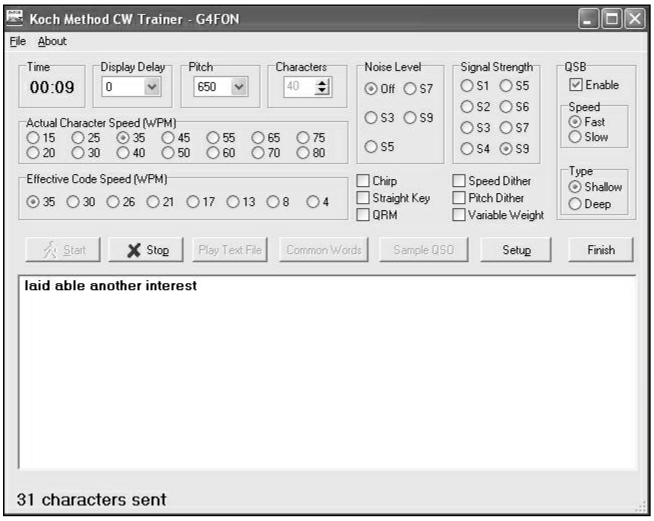

Fig 18.1: Part of the screen of the G4FON Koch Morse trainer program

dits and dahs and searches in a mental lookup-table for the right one. With a great deal of practice, speed increases but everyone who learns by this method experiences a 'plateau' at 8-10WPM where no more progress seems possible. Many aspiring CW operators give up in frustration at this point.

What is happening is that the process of responding to individual dits and dahs and looking them up in a mental table is hitting a natural upper speed limit. The student who can move beyond that limit has made the unconscious transition from the old 'lookup' method to a stage where the whole Morse character is recognised by reflex. Koch's insight was to see that it was essential that each character retain its acoustic wholeness and never be broken down by the student into dits and dahs. The essence of the Koch method is that the letters are learned one at a time, but with the correct rhythm and at full speed. There is no process of decoding the dits and dahs, but from the beginning a reflex is built, so that when 'dah-di-di-dah' is heard, it is automatically recognised as X without any conscious decoding process. It's the same way that a touch typist knows where the letters are on a keyboard without having to think about it.

Another key feature of the Koch method is that it provides positive reinforcement. Once a letter has been learned, it has been learned at full speed and it is possible to measure one's progress towards mastery of the full alphabet.

Koch's technique was difficult to implement for classes of students in the 1930s but has come into its own in the day of the personal computer, when each student can learn at his or her own pace. A program written by Ray Goff, G4FON, implements the Koch method and can be downloaded from [1]. Much of the credit for rediscovery and promotion of the Koch method must go to N1IRZ, and the G4FON program follows his suggested implementation.

The student starts by learning just two letters, at a speed of 15WPM. The program sends random combinations of these letters for a fixed period, typically three to five minutes, and the student must copy them onto paper. At the end of the run the copy is compared with what the computer sent, as displayed on the screen. If 90 percent or greater correct copy is received, a third character is added to the set and another run started. It is up to the student how many runs to do in a day. When Ludwig Koch carried out his investigations in the thirties he was seeking to train commercial operators but found that too many sessions in a day gave diminishing returns and the amateur student is more likely to have to fit in training sessions around other activities.

As the training programme progresses and more and more Morse characters are added, the student gains a real sense of achievement, and proof that it is possible to master the copying of Morse characters at full speed. G4FON's program introduces new characters in the order suggested by N1IRZ which mixes easy and difficult letters, numbers and punctuation in an apparently random order.

Once all 43 characters have been learned the program lets the student practice with text files (**Fig 18.1**), or with simulated contacts. At this stage, most people would also have started to listen to real contacts on the amateur bands, though the quality of 'real' Morse code can be rather variable.

The ubiquitous computer can have its dangers, as well. The Koch method is the quickest means of learning the code but some students in their impatience have resorted to use of Morse decoding software as an aid to getting on the air on CW more quickly. This approach leads to reliance on the computer and the temptation must be resisted.

Sending

Although the PC makes it possible for a student to learn Morse code without assistance, when it comes to sending by far the best approach is to get an experienced operator to listen and correct any bad habits at the earliest opportunity. The student who has learned using the Koch method may have fewer bad habits than most. If no-one is available to listen in person then one method that can work is to make tape recordings and play them back to try and discover weaknesses. Only when the student's sending sounds perfect should it be tried on the air.

MORSE KEYS

It is important to start by getting a good quality straight key ('pump handle') such as the one in **Fig 18.2**, and position it correctly on the table. Adjust the height of the seat so that when not sending, the arm is resting horizontally, and it requires only a small lift of the forearm to hold the knob of the Morse key. This should be held with the forefinger on top of the knob, the thumb to the left and slightly underneath the knob, and the second finger either on top or to the right of the knob (assuming a right-handed operator). Dots are made by a small wrist movement whereas dashes require a more pronounced downward movement of the wrist.

The forearm and the upper arm should make an angle of approximately 90 degrees. When sending, movement of the key should come from a combination of the elbow and the wrist. Often the key is mounted at the edge of the table but if it is further back, the forearm should be slightly above the table, not resting on it.

Bugs and Elbugs

With practice it is possible to send at speeds over 20WPM on a straight key, but the operator who aspires to high-speed (QRQ) working will sooner or later wish to learn how to use a bug.

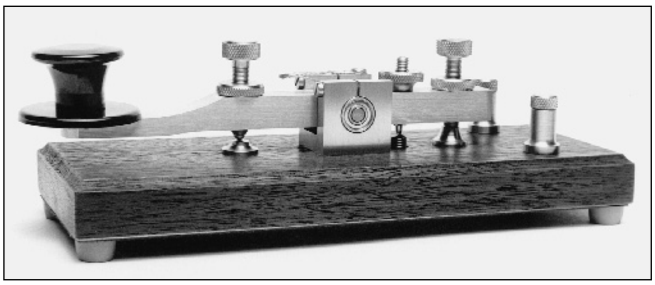

Fig 18.2: A modern straight key (photo: RA Kent (Engineers))

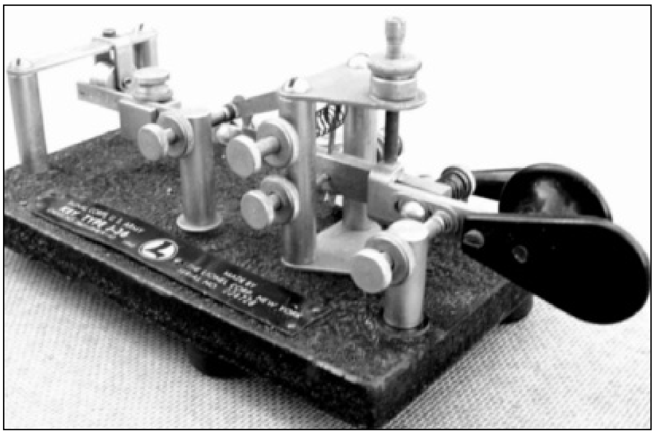

Fig 18.3: A mechanical bug key

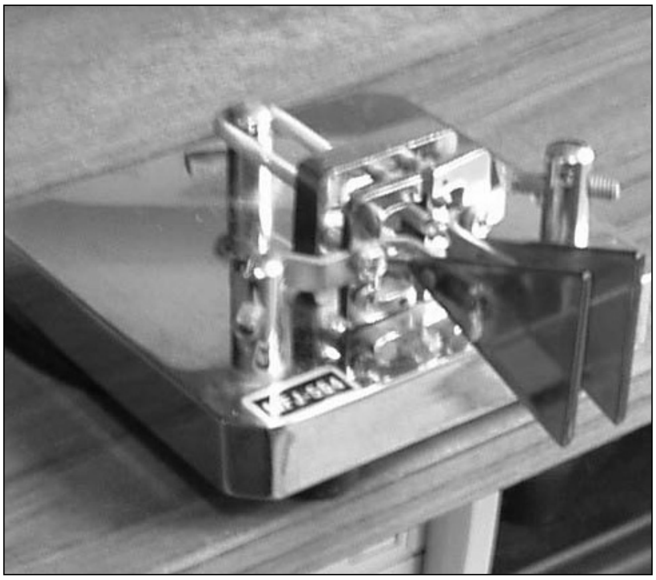

Fig 18.4: A paddle for use with an electronic keyer

The semi-automatic key (**Fig 18.3**), generally known as the bug after the trade mark of the original maker, is a mechanical key in which the arm moves from side to side instead of up and down. It has two pairs of contacts; dashes are made singly by moving the knob to the left, thereby closing the front contacts. A train of dots is produced by similarly moving the paddle to the right against a stop. This causes the rear portion of the horizontal arm to vibrate and close the rear pair of contacts. A properly adjusted bug key will produce at least 25 dots.

Bugs were in widespread use until the advent of the electronic keyer, or 'elbug'. The first elbugs were cumbersome affairs using combinations of relays and valves. Transistor types followed, giving way to IC-based keyers and now PIC and other microprocessor keyers. Most modern transceivers incorporate an electronic keyer, and station logging and computer logging programs provide a CW keyer as standard. Many programs support both paddle input and keyboard input so the operator can choose whether to use the program either as a keyer taking input from a paddle, or as a keyboard sender.

The key or 'paddle' (**Fig 18.4**) used with an electronic keyer is a derivative of the mechanical bug key, with movement from side to side instead of up and down. For the right-handed operator, moving the paddle to the right with the thumb produces a train of dots. Moving the paddle to the left with the side of the index finger produces a train of dashes. An iambic or 'squeeze' keyer requires a twin paddle key, and as well as movement of each paddle separately they can be squeezed together, hence the name. According to which contact is closed first, a train of either di-dah-di-dah or dah-di-dah-dit is produced.

As with the straight key, the newly acquired bug or electronic key should not be tried on the air until the operator has gained confidence through practice. Some electronic keys provide auto-spacing in an attempt to enforce the three- or seven-dit gaps between characters and words, but it is still just as easy to send bad Morse on an elbug as on a straight key.

A Simple Electronic Keyer

This keyer designed by E. Chicken G3BIK, is of basic design in that it uses only four integrated circuits and does not include the iambic facility. According to which side the paddle is moved, a

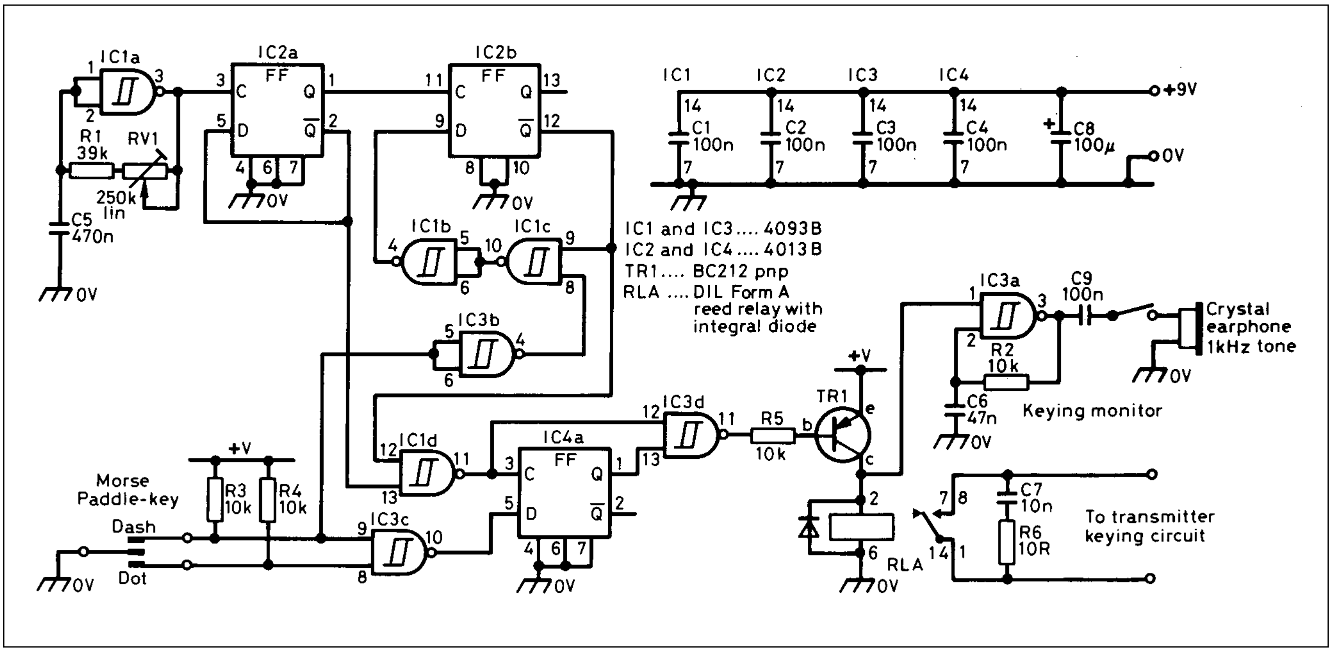

Fig 18.5: The G3BIK simple keyer uses four ICs for precision Morse

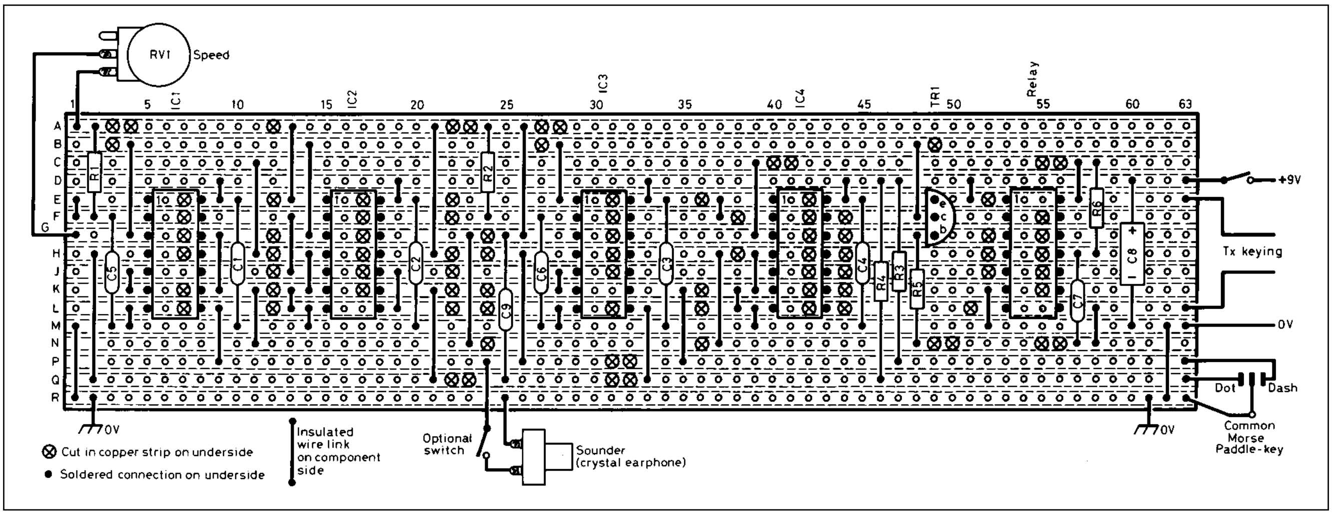

Fig 18.6: Construction of the G3BIK keyer is easy using strip board. The component side is shown

train of dots or dashes is produced. The speed is adjustable in the range 5-35wpm. A small sounder is included as a side tone (keying monitor). The circuit diagram is shown in Fig 18.5, and the stripboard layout is in Fig 18.6 . Details of the paddle key are contained in the full article [2].

CW TRANSMISSION AND RECEPTION

A crystal-controlled QRP transmitter for CW can be made with fewer than a dozen components, and give many contacts under favourable conditions. There are many designs for simple CW-only homebrew transmitters or transceivers and several kits are available that offer CW-only transmission.

Almost all commercial transceivers are designed with SSB in mind, and sometimes give the impression that CW has been added as an afterthought. Even the top of the range Yaesu transceiver, the FT1000MP, is known for its key clicks and several modifications have been developed - by individuals and not the manufacturer - to address this shortcoming in the design of an otherwise excellent piece of equipment.

In many transceivers a dedicated IF filter for CW is an optional extra. Some rigs incorporate passband tuning which can be used to narrow the receive bandwidth without the expense of buying additional internal filters. There are occasions under crowded band conditions when it is extremely difficult to separate the many CW signals that can pass together through an SSB filter, which may have a bandwidth of up to 2.5kHz. IF filters most commonly available to fit in a transceiver for CW reception have a bandwidth of 500Hz though 250Hz filters can sometimes be obtained.

In cases where IF filtering is not available, CW filtering can be done at audio frequencies, and combinations of IF and AF filtering can be extremely effective. The problem with audio filtering on its own is that any filtering done after the AGC detector will result in 'pumping' whereby strong signals which are not heard by the operator because of the audio filter nevertheless are let through by the IF filter and cause desensitisation of the receiver. More recent designs using IF DSP (digital signal processing) can help to address this problem by implementing the filter before detection, though the dynamic range of the DSP system may then become an issue.

Different operators have different styles, and some of the best contest and DXpedition operators like to use relatively wide filters and do most of the separation of CW signals in their head: it is sometimes said that the best CW filter is between the ears. Nevertheless there are times when a narrow IF filter is essential for pileup and weak signal CW work.

A very simple add-on audio filter which provides some selectivity as well as helping to clean up the hiss, clicks, hum and thumps which spoil the audio of some rigs, has been described by Fraser Robertson, G4BJM [3]. In its simplest form it consists of a simple series-resonant circuit and with the inductor and capacitor values shown in Fig 18.7 it resonates at around 730Hz. The components can simply be wired inline as a headphone extension lead, and covered with self amalgamating tape or heat-shrink tubing to provide some mechanical stability. Alternatively, it can housed in a small box as in Fig 18.8.

Most transceivers incorporate semi break-in or 'VOX' keying on CW. This means that the user does not have to operate a separate transmit/receive switch, but transmission starts automatically almost at the instant that the key is pressed. The equipment returns to receive a short period after the key is opened, and this period can usually be varied. The intention is to ensure the rig stays in transmit between Morse characters, but returns again to receive without the operator having to throw a switch.

Full break-in ('QSK') is also frequently implemented, with a varying degree of success. Full break-in means that the operator

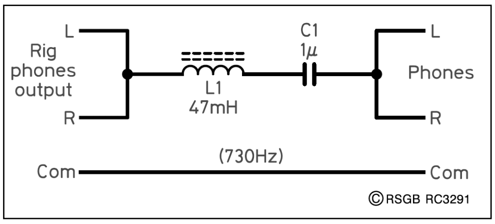

Fig 18.7: Circuit of the two-component CW filter

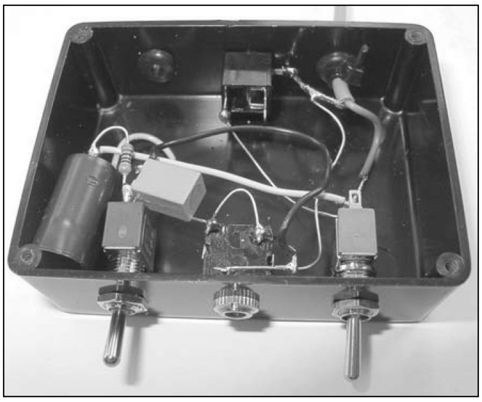

Fig 18.8: The deluxe version of G4BJM's two-component filter includes switches to connect a loudspeaker, and to bring the filter in and out of circuit

can listen between the individual dits and dahs of a Morse character, right up to 40WPM and beyond. With careful transceiver design this goal can be achieved, but design compromises and shortfalls generally mean that a number of manufacturer's implementations are far from perfect. Ten-Tec and Elecraft have, however, really understood the design principles involved.

When examining the keying waveform of many amateur transceivers, the correct 1:1:3 ratio between spaces, dits and dahs is not always maintained or if it is, this is at the expense of reduced receive time when using full break-in. A common feature of poorly designed rigs when using semi break-in is a short first dit, because of time taken in the transceiver to switch between transmit and receive. If this is used to drive an amplifier which itself has a slow T/R relay, the overall effect in extreme cases can be to lose the first dit of a transmission altogether.

If an oscilloscope is available it can be used to display the outline of the pattern made by the signal, this is called the keying envelope. The keyed RF signal is fed to the Y-plates or vertical amplifier of a slow-scan oscilloscope, with the timebase set in synchronism with the keying speed. The square shape in **Fig 18.9(a)** is a very 'hard' signal and will radiate key clicks over a wide range of frequencies. The transceiver design should ensure that the rise and fall times are lengthened such that interference is no longer objectionable, but without impairing intelligibility at high speed. The goal should be to achieve rise and fall times of about 10% of the dit length (**Fig 18.9(c)**).

The characteristics of the power supply may contribute to the envelope shape, as the voltage from a power unit with poor regulation will drop quickly each time the key is closed, and rise when it is released. This can lead to the shape in **Fig 18.9(d)**.

QRSS AND DFCW

Not all Morse used on the amateur bands is intended for reception by ear. When a signal is transmitted over fairly stable paths, such as on 136kHz, it can be received well below the threshold of audibility by using a computer's sound card and software [4] that displays the signal as dots and dashes on the screen.

QRSS is extremely slow speed CW, with dot lengths from three to 120 seconds. The name is derived from the Q-code QRS (reduce your speed). To take advantage of the very narrow bandwidth of the transmitted signal an appropriate filter at the receiver end is needed. Making a 'software filter' using Fast Fourier Transform (FFT) [5] has some advantages over the old fashioned hardware filter. One of the main advantages, when using it for reception of slow CW signals, is that FFT does not provide a single filter but a series of filters with which it is possible to monitor a complete spectrum at once. This means that it is not necessary to tune exactly into the signal, what can be very delicate

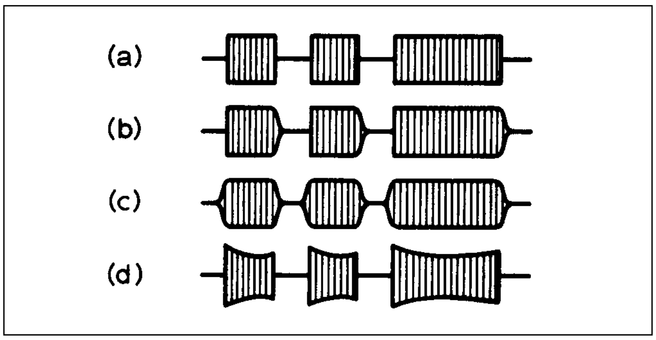

Fig 18.9: Keying envelope characteristics. (a) Click at make and break; (b) click at make with click at break suppressed; (c) ideal envelope with no key clicks; (d) affect on keying envelope of poor power supply regulation

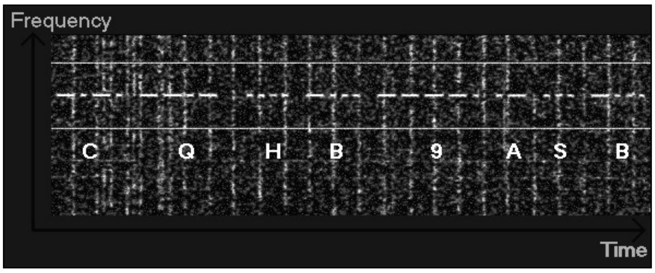

Fig 18.10: A QRSS signal on a curtain display. The translated letters have been added to the picture; they are not present on the original display. The vertical lines are static crashes [pic: ON7YD]

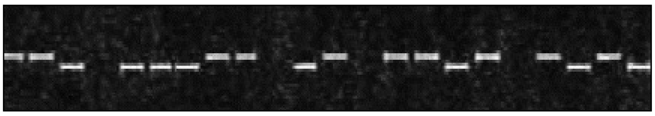

Fig 18.11: DFCW uses different frequencies instead of dots and dashes. This says "G3AQC" [pic: ON7YD]

at sub-Hertz bandwidths. Also it is possible to monitor more than one QRSS signal at the same time.

At first glance it looks as if it is complicated to do this, even if FFT presents you this nice multi-channel filter it might be difficult to monitor all these channels. Further the long duration of the dots and dashes is unfavourable for aural monitoring.

A solution to the above problems is to show the outcome of the FFT on screen rather than making it audible. The result is a graphic where one axis represents time, the other axis represents frequency and the colour represents the signal strength. If the vertical axis represents time it is called a waterfall display, while a curtain display is where the horizontal axis represents time (**Fig 18.10**).

A variant of QRSS is Dual Frequency CW (DFCW) where the dots are transmitted on one frequency, and the dashes on a slightly higher frequency (**Fig 18..11**). This saves time as the dashes can be the same length as the dots. In fact, a time reduction of better than 50% can be achieved, which can be very important at these extremely slow speeds, especially when trying to fit a contact into a relatively small ionospheric propagation window.

SUMMARY

In summary, Morse should not be seen as daunting. Thousands - millions - of people have mastered the use of Morse code over the years and many amateurs continue to use it on a daily basis. A 5WPM Morse test is counterproductive, because it encourages people to start slow and try to build up speed gradually. Ludwig Koch showed in the 1930s that there was a better way and by using G4FON's program it's possible to acquire CW receiving skills which can be of practical use on the amateur bands.

REFERENCES

[1] Computer program for learning Morse code. http://www.g4fon.net
[2] 'The BIK Simple Electronic Key', Ed Chicken, G3BIK, *Radio Communication* Aug 1993
[3] 'A Two-Component CW Filter' Fraser Robertson, G4BJM, *RadCom*, Aug 2002
[4] Viewers for QRSS and DFCW can be downloaded from http://www.weaksignals.com
[5] QRSS and DFCW information at ON7YD's web site http://www.qsl.net/on7yd/136narro.htm