All About Squeeze-Keying (part 1)

by Karl Fischer, DJ5IL

Radio amateurs invented and pioneered electronic Morse code keyers, but today their knowledge of the different twin-lever keying modes is sparse. Here is a review and thorough explanation ...

RADIO HAS TRANSFORMED society, it revolutionized long-distance communication and gave birth to the entire field of electronics. For many decades Morse code telegraphy has been the backbone of two-way communication with this fantastic medium because it was most effective even under difficult conditions. Though abandoned by most radio services, telegraphy or CW (continuous wave) is still used and revered by many amateur radio operators worldwide. Before we treat the main subject of this article, namely the operation of twin-lever electronic keyers, let us take a brief look at the most important evolutionary steps that led to and refined their predecessor, the single- lever electronic keyer or "el-bug" ...

From straight key to el-bug

The American telegraph pioneer **Alfred Lewis Vail** was born in Morristown, New Jersey, in 1807. Shortly after his graduation from University in 1836 he met Samuel F. B. Morse, was fascinated by Morse's telegraph experiments and became his associate. In return for a share in the rights he agreed to construct telegraph equipment and to bear the costs. Morse had brought the principal idea of sending messages by wire and he also experimented, but it was Vail who devised and built the actual instruments as well as the "Morse code" which the system used.

In May 1844 the famous telegraph message "What Hath God Wrought" travelled almost instantaneously across the 40 miles between Baltimore and Washington D.C., America had entered the information age.

The telegraph exploded and within 10 years 23,000 miles of telegraph lines crossed the country.

During previous tests of the Baltimore-Washington line, Vail began to send the code which he had developed by dipping the wires into mercury cups by hand, and shortly after he devised the first crude telegraph key called the "Finger Key". Then he designed an improved version, the "Lever Correspondent", and two of these keys were used in that first demonstration of the telegraph to Congress. The operators of that first telegraph circuit were Alfred Vail at the Baltimore Railroad Station end and Samuel Morse at the Washington end.

The classic telegraph *straight key* is essentially a big, precise, normally open momentary contact, which is operated vertically. But almost as soon as the telegraph industry was formed, the "telegrapher's paralysis" or "glass arm" (repetitive strain injury, RSI) caused by the up and down motion became the

occupational disease of the landline telegraph operators of these days, as they had to put out thousands of words in a single trick.

Jesse Bunnell was born in Massillon, Ohio, in 1843, one year before Samuel Morse sent the first telegraph message. At age 11 he became a messenger boy, at 13 he was a full-fledged telegraph operator and at 17 he set a telegraph speed record of 32 words per minute. Jesse was a champion telegrapher and "one of the ablest and bravest operators" of the Union Military Telegraph Service UMTS. In 1878 he created the J. H. Bunnell & Co. in New York City.

It was soon discovered that a side-to-side motion was easier on the hand, and at the beginning of the 20th century the wave of horizontally operated keys and the interest in them was rapidly growing. In 1904 Bunnell & Co. formally introduced its new *"Double Speed Key"*, which was invented already in 1888 and which had the potential to help a telegrapher to achieve two goals: higher speed with less physical strain. This device, which was later called *sideswiper* or *cootie key*, is basically a straight key turned on its side with contacts in both directions.

(Patented)
No. 5876.

THE DOUBLE SPEED KEY.

Improved Contact Holders.

Requires but one-half the motions of the ordinary key, and these are made by a sidewise rocking motion of the hand, easily acquired, which guarantees that operators will not be affected with cramp, and those who are so affected will soon recover their

SPEED AND STYLE.

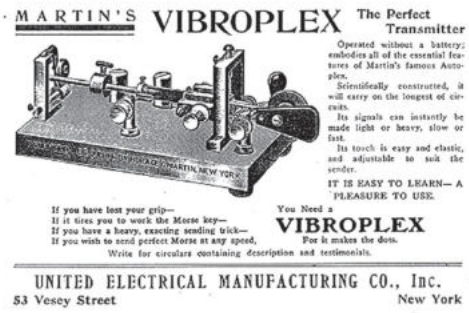
Condemned by every operator at first glance, but on reflection this judgment is quickly reversed, and a trial or demonstration creates enthusiasm, and free predictions that it is the

COMING KEY.

It is simple and inexpensive. It is attractive in appearance. It can be quickly mastered. It is made exclusively by the manufacturers of the best telegraph instruments on earth.

Properly operated, each character starts with a movement of the lever to the same side (which side is your choice - but once you have decided, stick to it !) and then the lever is moved horizontally back and forth between the contacts, so that the elements of a character are formed strictly alternating between the right and left contact. The sideswiper is the fore- runner of all electronic keyers.

As a youngster **Horace Greeley Martin** spent his time at a train depot in Adairsville, Georgia, were he learned telegraphy. Western and Atlantic Railroad discovered his talent an hired him as an extra operator when he was only nine, later he worked for the Associated Press and developed the reputation as being one of the best senders ever in the press service.



The first *semi-automatic key* was manufactured and sold in 1905 by the Vibroplex Company, New York City, after it was invented and patented by its founder Martin in 1904. Pressing its lever to one side makes a continuous contact for sending dashes. But pressing it to the other side sets a pendulum arm into vibrating motion, and by making and breaking contact a series of dots is generated at a speed which is controlled by the position of the pendulum weight. Other companies devised different methods to generate a stream of dots, but Martin's original design was the most reliable and certainly the most imitated.

In the late 19th century, long before this key was invented, telegraphers associated false signals heard on duplex landline circuits with a "bug" and the wire was considered "bugs" or "buggy". The origin for that terminology is said to be a

cockroach covered in ink which once crawled across a rheostat and caused the duplex circuit to go out of balance. Soon after the first semi-automatic keys appeared on the wires, the telegraphers started to call them "bug", because they frequently sounded like a buggy circuit when they were misadjusted. Only in 1920 a little insect depicting a lightning bug appeared on the name plate of the Vibroplex keys, and that famous logo as well as the name "BUG" became a copyright of the Vibroplex company. The first wireless operators were landline telegraphers who left their offices to go to sea or to man the coastal stations. They brought with them their language and so the nickname "bug" for any semi- automatic key regardless of the manufacturer became generic.

Before we continue, let us have a look at the correct timing of Morse code. The keying speed can be expressed either in WPM (words per minute) or in CPM (characters per minute) with CPM = 5 x WPM. From that we can calculate the length of a dot, which is the basic timing unit, and deduce the length of a space (pause between dots or dashes within a character), inter-character space (pause between characters) and inter-word space (pause between words) in milliseconds (ms) as follows:

dot = 1200 ms / WPM
= 6000 ms / CPM
space = dot
dash = 3 x dot
inter-character space = 3 x dot
inter-word space = 7 x dot

Harry Beecher, W2ILE, of Milltown, NJ, deserves to be recognised as the true originator of the practical electronic keyer. His article *"Electronic Keying"*, sub- headed *"An Electrical "Bug" Which Makes Both Dots and Dashes"*, appeared in April 1940 [1] and presented a circuit based on two valves and three high-speed relays. Thereafter, several authors published changes to his design as well as their own circuit ideas.

Then, in August 1945, the pioneer of the electrical bug - short "el-bug" - published *"A Better Electronic Keyer"* [2] which generated more dependable dots and dashes while requiring less circuit alignment than his first model. All previous el-bug designs required the operator to hold the lever closed until the space to prevent a curtailed dot or dash from going out. A major advance made by W2ILE was to introduce the concept of *self-completing* dots and dashes and the enforcement of the following space period, making this keyer much easier to handle than any of its predecessors and allowing *"precise, compact characters at high speeds with less effort"*. Now we can say that starting with the self-completing feature any electronic Morse code keyer is able to generate basically two types of character elements: a *dot-element* (dot + space) or a *dash-element* (dash + space). Note that the space following a dot or dash is part of the element.

A major step forward in valve-type electronic keyers should be attributed to **Forrest A. Bartlett, W6OWP**, who published *"Further Advances in Electronic-Keyer Design"* in October 1948 [3]. He simplified and optimized Beecher's original design and also explained the advantages of self-completion in detail. Bartlett's el-bug had just one speed control, whereas Beecher's had three: one to set the dot length, one to set the dash length, and one to set the space length. If that wasn't a beast to align, the operator still had to periodically adjust the custom-made lever which had three (!) pairs of contacts. The result was an el-bug with *"self-completing dots and dashes, single-control speed adjustment and a simple keying lever - all*

without undue circuit complication" - and needless to say, Bartlett's design was far superior to Beecher's.

Bo Brøndum-Nielsen, OZ7BO, was a brilliant radio engineer and one of the best-known Danish radio amateurs, renowned for his superlative CW "fist" which made him a legend in his own time. But few knew Bo had also been an important member of the highly successful Danish wartime clandestine radio organization, who designed and built many compact shortwave transmitters and receivers for the Danish underground while his country was occupied by German forces. When the "First Class CW Operators' Club" FOC was re-formed after WW2, he became its first non-British European member with certificate number 27. Bo worked for "Det Store Nordiske Tele- graf-Selskap" (The Great Nordic Telegraph Company), headquartered in Copenhagen, and in 1947 he and others from that company formed "Storno", the first mobile two-way radio company in Denmark.

Being an engineer and ardent CW operator, Bo had followed the various published el-bug designs and finally experimented with the W6OWP circuit which, despite its simplicity, overcame many of the snags associated with the earlier designs. In order to make use of components readily available in post-war Europe, he made a number of modifications and simplifications and published his circuit in the February 1949 issue of "OZ", the journal of the Danish Amateur Radio Society EDR. Bo's simple el-bug was soon the talk of radio amateurs all over Scandinavia and a translation of his original article appeared in the "RSGB Bulletin" of February 1950. The OZ7BO el-bug was acclaimed for the quality of code it produced, which was far superior to that of semi-automatic "bug" keys, and became an immediate success. Thousands of them were built and operated (not only) by radio amateurs between 1949 and the mid 1960's.

In April 1951 Jack **Herbstreit, W4JNX**, published the article *"Automatic Spacing of Letters and Words for the Electronic Key"* [4]. His keyer design used five valves and generated self-completing dot- and dash-elements. While the circuits of W2ILE, W6OWP and OZ7BO were based on lever-actuated time-base oscillators, so that a dot or dash started immediately with the closure of a lever-contact, W4JNX used trigger pulses from a continuously running time-base with a period of two dot-lengths to support proper spacing between characters and even words. These trigger pulses are routed through the lever's dot- and dash-contacts, so that dots and dashes are triggered by the pulses but only enabled as long as the associated lever-contact is held closed. Waiting more than one but less than three dot-lengths after a character or more than five but less than seven dot-lengths after a word before closing a lever-contact, the associated dot or dash starts with the next pulse and therefore with the correct spacing of three (inter-character space) or seven (inter-word space) dot-lengths.

However, this scheme results in an uncontrollable beast: it chains the operator to an inexorable time- base and forces him to apply spacings which are more or less too short, because if the lever is not pressed at the instant of a pulse the correct spacing is forfeit. And if it is pressed in between pulses nothing happens until the next pulse comes along, which in the words of the author is *"sometimes very disturbing in attempting to operate the key"*. W4JNX concluded that he does *"not feel that any but the most feverish electronic key enthusiasts will wish to build one of these infernal, maddening machines"*. Nevertheless, he hoped that the idea might

"provide an inspiration for further development in that field".

John Kaye, W6SRY, accepted that challenge and came up with a rather ingenious design, which was published in 1953 as *"The "Ultimatic" - The Key with a Memory"* [5] with the following comment by the Editor: *"Here is something that comes as close to being an electronic brain as you are likely to encounter in amateur radio. A big step forward in the automatic- key field"*. The circuit is based on three valves and a whopping seven relays and sticks to the continuously running time-base, which allows to generate the pro- per spacing between characters and words but retains the major drawback of the previous design: pulses from the time-base trigger the generation of dot- and dash-elements, and so they do not start immediately with the closure of a lever-contact but only with the next pulse. And so without further measures leading elements of a character would often be lost.

However, what made Kaye's design special was the addition of a *dot-memory* and a *dash-memory* together with a *sequencer*. The contacts of the two dot/dash-memory relays are each in parallel with their lever-contacts and a closing contact of the single-lever key activates (sets) its memory relay, which keeps itself closed and simulates a closed lever-contact independently of the lever state. Pulses from the time- base are passed as triggers to the dot or dash-generator only if the related lever- or memory-contacts are closed. Only one contact of the single-lever key but both memory relay contacts can be closed at the same time, and a sequence relay makes sure that the gates passing the pulses are opened in the proper order of storage. If a gate is open the next pulse from the time-base activates the selected generator relays, which generate the desired element and deactivate (clear) only the related memory relay. Note that the memory relay is cleared already at the *onset* of the associated element, and therefore while an element is generated another element of the same type can be stored.

This combination of a *dot-memory* and a *dash- memory* with *sequencing* avoids dropping of elements and provides considerable timing leeway by allowing the storage not only of a single dot *or* dash but of a whole dot + dash or dash + dot sequence at any time. According to W6SRY these features together with automatic character- and word-spacing transformed the "beast" of W4JNX into a "beauty" and he proclaimed: *"with the key set for 10 w.p.m., you can hit a 40 w.p.m. 'N' and walk away while the key produces a slow 'daah-dit'..."*

Ultimatic mode

While all el-bugs up to this time including the previous design of W6SRY still used a single-lever key, his next version which appeared in 1955 as *"The All- Electronic "Ultimatic" Keyer"* [6][7] was the first twin-lever keyer and the ancestor today's modern squeeze- keyers, and it is this keyer's action that gave the ultimatic mode its name. The circuit is based on 11 valves and only one relay and the time-base, dot- and dash- memories and sequencer are functionally identical to the first single-lever version.

While only one lever-contact is held closed it generates a string of dots or dashes, exactly like any single-lever keyer does. But because contrary to that twin-levers can be squeezed so that both lever-contacts can be closed at the same time, a *seizure* circuitry was added: whenever a lever makes contact, it seizes control regardless of the state of the other lever and the subsequent elements correspond to that lever until it is released or the other lever makes contact. One dot or/and one dash can be stored at any time and in any

order by momentary closure of a lever-contact, and the sequencer makes sure that they are injected in proper order after the current element. So any closure of a lever-contact guarantees at least one element of that type, generated in correct relationship to the order of closure. For example, to key an "X" press the dash-lever for the first dash and hold it, then press also the dot-lever so that both levers are *squeezed* for the middle two dots, release only the dot-lever for the last dash and finally release the dash-lever. This keyer can be treated like a semi-automatic bug key or a single-lever keyer or with any intermediate technique, but its full potential can be discovered only with the squeeze-keying technique. It is able to send perfect code without the need for the operator to send it perfectly, or as W6SRY put it: *"a key that gives Klein output with Lake Erie input. It does everything for the operator but spell and punctuate"* [8].

The twin-lever Ultimatic based on pre-digital age logic with automatic character- and word-spacing plus separate dot- and dash-memories was indeed a breakthrough design and way ahead of its time. A solid-state version with 17 transistors was built and published in 1960 [9][10] by Alvin F. Kanada, KØMHU. Compared with simple el-bugs the first single-lever Ultimatic already mitigated timing requirements and did away with the sensation of being chained to an inexorable time-base. The twin-lever version greatly reduced hand motion as well, but characters still started more or less delayed after a lever was hit. This nuisance would be totally unacceptable today and does no longer exist with the ultimatic mode emulated by some modern electronic keyers.

"Squeeze" keying is the brainchild of W6SRY, since in that article he coined the term and explained the concept. Operating a single-lever keyer requires a rocking motion of the whole hand to form a character, while a twin-lever keyer can be operated by moving just the thumb and forefinger and thereby obviating the fight against the hand's inertia. If you think that it is also possible to operate a single-lever keyer moving only your thumb and forefinger, try it while carefully watching your hand. You will realize that with increasing speed you inevitably fall back into a rocking motion of the whole hand.

Of course, the mere existence of two levers instead of one will not force you to move only your thumb and forefinger, unless you obey the following single and very simple *squeeze-keying rule:*

keep a lever pressed as long as possible by releasing it only during the last possible element of the character.

This technique not only prevents needless rush, it also minimizes finger movement as well as the rocking motion of the whole hand. Its most obvious effect is that both levers are often *squeezed* together, but its most important effect is highest possible keying efficiency which means higher speed with less effort and errors. Let us define a stroke as the closure of a lever-contact and introduce three *figures of merit* which can be used to characterize any twin-lever keying mode:

1) **stroke rate:** the average number of strokes per character. It is calculated as the total number of strokes necessary to key all 26 letters of the alphabet and all 10 digits divided by 36.

2) **hold time:** the average maximum possible time in dot lengths a lever can be kept pressed. It is calculated as the total time of closure for each contact, operated with the earliest possible attack and latest possible release, when keying all 26 letters of the

alphabet and all 10 digits divided by the total number of strokes.

3) **persistence:** the percentage of characters thereof which can be keyed by keeping the initial lever pressed throughout the entire length of the character, no need to let it go, whilst only operating the other lever.

The lower the *stroke rate* and the higher the *hold time* and *persistence*, the higher is the *efficiency* of a keying mode. It should be obvious that the efficiency depends on the stroke rate, but why is it affected also by the hold time and persistence? Because the higher their value, the less hasty is the movement of the thumb and forefinger which means 1) less fight against inertia and therefore less effort and more efficiency and 2) less critical timing and therefore fewer errors.

The ultimatic mode is characterized by the following properties: the stroke rate is 1.78 (64 / 36), the hold time is 9.7 (618 / 64) and the persistence is 100% since all characters without exception can be keyed by keeping the initial lever pressed. Neglecting those characters which require just a single stroke, all other letters of the alphabet except for the "C" and all other digits can be keyed with just one closure of each lever- contact which equals two strokes.

Owning a two or three tube el-bug in the 1950's was looked at by some as a luxury appliance, Kaye's demanding 11 tube Ultimatic was therefore seen as an extravagance and maybe that's why it never gained popularity. In October 1957 the Soviet Union started the space age by launching the first man-made satellite "Sputnik 1" into earth orbit. Many radio amateurs were riveted to their receivers trying to pick up Sputnik's signals, the general outlook on electronics changed rapidly and also the electronic keyer became viewed as a good project to build for advancing one's knowledge of logic circuits.

In 1962 **Dave Muir, W2VYO**, published his transistorized *"Penultimate Electronic Key"* [11] with the purpose to fill the gap between simple el-bugs and the very ambitious Ultimatic. It was a single-lever keyer like the very first Ultimatic of 1953, but W2VYO abandoned automatic spacing in favour of a lever-actuated time-base, so that he got rid of the Ultimatic's principal deficiency and characters started immediately with the closure of a lever-contact.

As a result, dropping of leading elements was not a problem any more, but he recognized the problem of dropping single dots embedded between two dashes or ending a character after a dash which he described as follows: *"For example, in the letter K, I would key the first dash, then go to the dot contact and back to the dash contact before the completion of the first dash. The result was a dropped dot and a perfect letter M [...] Similar experience in dropping final dots on letters such as G led to the provision of dot memory in this keyer circuit"*. Therefore, he implemented a dot-memory only because the longer duration of dashes makes their timing much easier. ■

To be continued.

References:

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2. Beecher, Harry, W2ILE, "A Better Electronic Keyer", QST, August 1945, page 44.
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5. Kaye, John, W6SRY, "The "Ultimatic" - The Key with a Memory", QST, February 1953, page 11.
6. Kaye, John, W6SRY, "The All-Electronic "Ultimatic" Keyer", Part I, QST, April 1955, page 11.
7. Kaye, John, W6SRY, "The All-Electronic "Ultimatic" Keyer", Part II, QST, May 1955, page 36.
8. "Klein" is short for Edward E. Kleinschmidt who was born in Germany in 1876 and immigrated to the United States at the age of 8. While still in his teens, he first patented a Morse keyboard transmitter in 1895, and so "Klein output" obviously stands for perfectly timed Morse code. In 1924 Kleinschmidt and the Morkrum Company decided to merge, later the company name was changed to "Teletype Corporation" and in 1930 it was sold to the American Telephone and Telegraph Company for $30 million. Kleinschmidt, a prolific inventor who obtained 118 patents, died in 1977 at the age of 101. The so-called "Lake Erie Swing" was a typical semi-automatic "bug" keying style of marine operators on the Great Lakes, characterized by short dots and dashes of exaggerated and varying length. This made for a somewhat melodic and musical sound, quite pleasant to copy once one got the hang of it. It was later adopted by many airline and police CW operators.
9. Kanada, Alvin F., KØMHU, "The "Ultimatic" - Transistorized", Part 1, QST, September 1960, page 27.
10. Kanada, Alvin F., KØMHU, "The "Ultimatic" - Transistorized", Part 2, QST, October 1960, page 31.
11. Muir, Dave, W2VYO, "The Penultimate Electronic Key", QST, March 1962, page 15.

W5 Area FOC On the Air Event

by Marv Bloomquist , N5AW

FOR OVER 20 YEARS there has been an annual gathering of FOC members at a location in the US 5th call area. Unfortunately, due to Covid 19 the 2020 and 2021 events had to be cancelled. However, as a substitute this year we had an on the air event the last weekend in April – the weekend the 2021 event was originally scheduled. Five FOC member club stations were on the air Saturday, April 26. They were W5FOC, WA5FOC, and KT5FOC in Texas, K5FOC in Louisiana, and N5FOC in New Mexico. These calls were passed around among twenty 5th call area members who signed the FOC calls from their home stations.

KT5X K1JD AD5A

All together 607 contacts were made with 101 FOC members. While a few were "contest style", most were at least short chats and several were longer "ragchews". Unfortunately, conditions were rather poor and only a few contacts were with members outside of North America. However, G3RVM and ZL2IFB both managed to make three QSOs – the most by our overseas members.