TRIAMBIC KEYER

by Mike Rhodes G4FMS

Morse code isn't everyone's forte and I often wonder whether the majority of those who have come to find it an intriguing method of communication would have done so had it not been for compulsory learning at some stage. The Radio Amateur, who requires a knowledge of the code before being permitted to operate on the h.f. bands is a case in point. I also wonder how much this enforcement influences the operator in his choice of a code generating device. Use of the basic "up and down" key is another requirement and although there's something to be said for such a primitive device and it does have an enthusiastic following, many amateurs look for something easier to use after passing the test.

Thinking a little further along these lines, one might ask the same sort of questions about the various styles of keying paddles that are currently in use. These have evolved over the years but without the co-existence of what we might call "compact" electronics. The full-blown keyboard is another device which has more recently appeared on the Morse scene. This may have plenty of associated electronics but the original idea came from the mechanical typewriter. Why not start from the present time and reconsider the problem? Using currently available components, what sort of device might the Radio Amateur find best suited to his needs?

This is no mean question and despite a strong lobby from the "left foot operators" association, in the end I had to narrow the field and conclude that the use of the left hand is probably the most convenient arrangement leaving the right hand free for operating the rig and pencil. (Left-handed scribes vice-versa). This immediately dismisses the keyboard as a medium, since it requires two hands and, incidentally, some typing ability.

A New Approach

So here we are back to one-handed operation—nothing new in that! But perhaps it's possible somehow to improve ease and efficiency.

Observation of the technique for operating a standard (telegraph) key convinced me that most of the skill developed is used firstly to eliminate contact bounce and secondly to time key depressions accurately. How much better it would be if, in the first place, we chose a switch specifically designed to reduce contact bounce to a minimum. The keyboard switch is such a device—light in action, good for a few million operations and, moreover, cheap. It's also quite fast in operation—just listen to your typist at her word-processor.

So, having found a suitable switch, the next problem is timing. There are many circuits around for twin paddle keyers where one paddle operates the dash and the other the dot. These produce self-completing dashes and dots of precise duration and may even include circuitry for defining the minimum gap between characters. Also, to reduce the number of paddle movements, the "Iambic" mode has been developed so that alternate dashes and dots are produced when both paddles are "squeezed" at the same time. This sort of circuit could be used with two keyboard switches and indeed this was an arrangement I used for a considerable time.

The Double Dot

However, it soon became apparent that because the "dot" and its following interval take only half the time duration of the "dash" and its following interval, then the time available for pressing and releasing the dot key is only half that for the dash key, so that more speed and skill is required by the "dot" operating finger. This lead to the idea of splitting the "dot" function between two keys, making three keys altogether, and so equalising the skill level required for the operation of each key.

The "dot" action is split between the two keys by making the first generate a self-terminating single dot with no repeat available and the second generate a self-terminating sequence of two dots (letter I) but in this case the action can be repeated by holding the key into the next "double dot" time period in a similar way to the dash repeat action. The double dot operating finger now has the same timing requirements as the dash operating finger and the single dot can be operated at the same sort of speed since it is only going to produce one dot even if held for twice the duration. To ensure that correct spacing is maintained between the elements of a character, each key must be electrically buffered so that regardless of the speed at which different keys are pressed, as long as they are pressed fast enough, the Morse output will be perfectly timed. An experimental circuit was devised to produce the required action and it also included an iambic mode facility to reduce the number of key movements as mentioned earlier(1).

Operation

The use of three keys will of course require a short learning period in order to memorise the required key combinations. If we label the three keys "E", "I" and "T" after their respective functions, a rudimentary fingering table can be constructed, see Table 1.

It will soon be found that some of the combinations can be keyed very rapidly indeed. Consider for example the let-

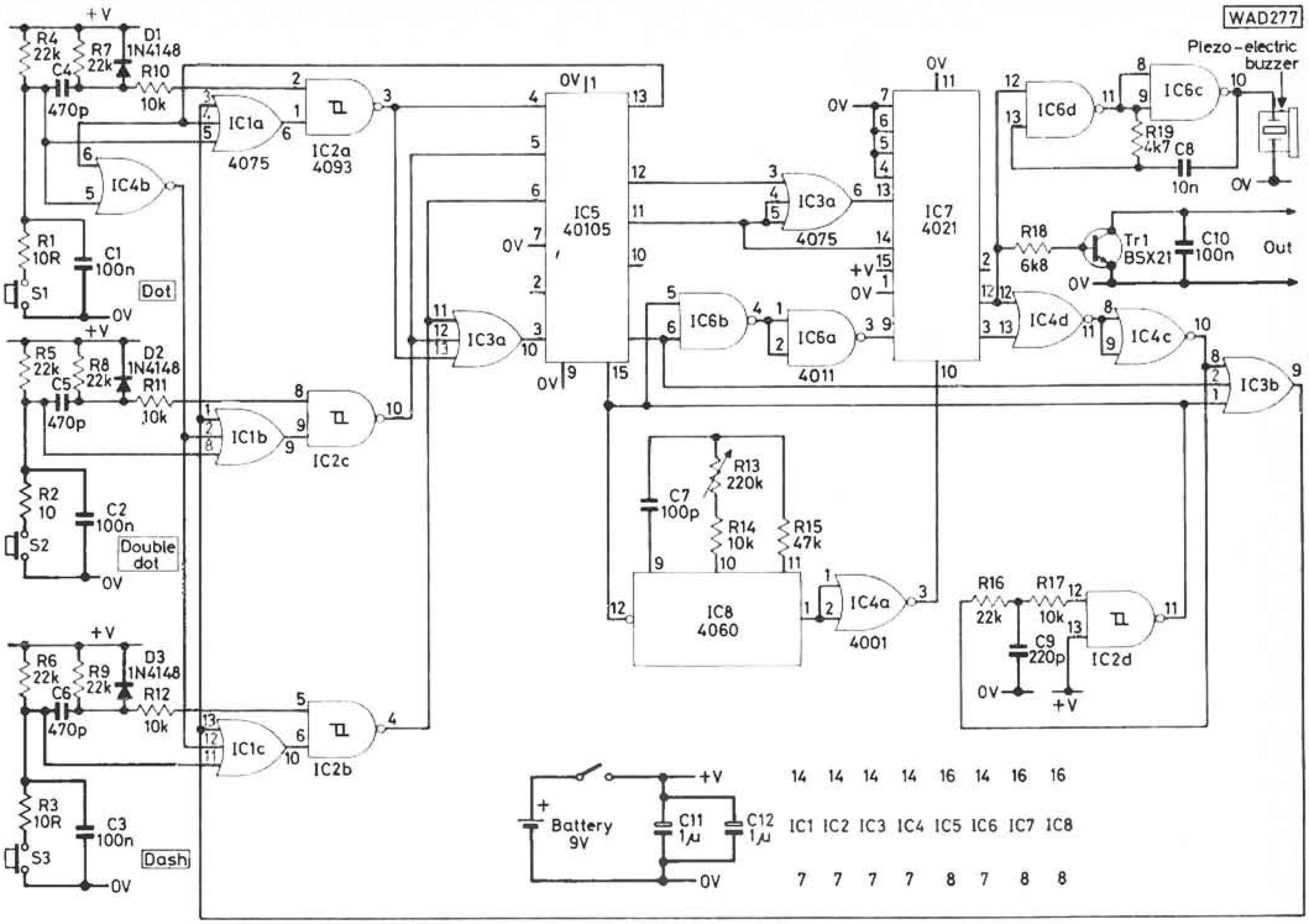


Fig. 1: Circuit diagram of the Triambic Keyer

ter F (di-di dah dit) which can be broken down as I-T-E. With the buffer provided, which gives a sort of type-ahead facility, the three keys can be struck in rapid succession, after which the operator can just wait for the keyer to complete its output before starting the next character. Again the letter S is particularly easy since the two keys I and E can be struck simultaneously and the three dots will appear at the output in due course.

At this stage I should issue a serious warning: **This keyer may become addictive.** The real advantage of the mechanism is probably not too obvious until you've tried it! It appears to have a much more rhythmic action in use than a standard paddle but the operation is by no means de-skilled. The selection of finger sequences soon becomes automatic and extra practice just makes excellent Morse perfect!

The FIFO Way

The only real problem with the prototype keyer was the size and complexity of the circuit which at the time of construction was considered of secondary importance to proving the principle. A cheap, compact and easily built unit was required to enable operators to test ideas for themselves. This has lead to the development of the f.i.f.o. Morse sender.

The f.i.f.o. itself (first in first out) which comes in the usual insignificant looking 16-pin d.i.l. package has integrated much of the original circuitry. It is, in effect, just a queueing buffer which takes inputs in turn—in this case from the keyboard switches—and permits them to appear at the output in the same order but at a different rate—here determined by the setting of the desired output Morse code speed.

Using the f.i.f.o. has enabled the number of integrated circuits to be reduced to eight, which brings the size and cost into comparability with other c.m.o.s. keyers.

BUYING GUIDE

Components for this project should be readily available. The 40105 f.i.f.o. device is available from Maplin, order code QW63T. The key switches and tops are available from Cirkit.

Approximate Cost
£16

Construction Rating
INTERMEDIATE

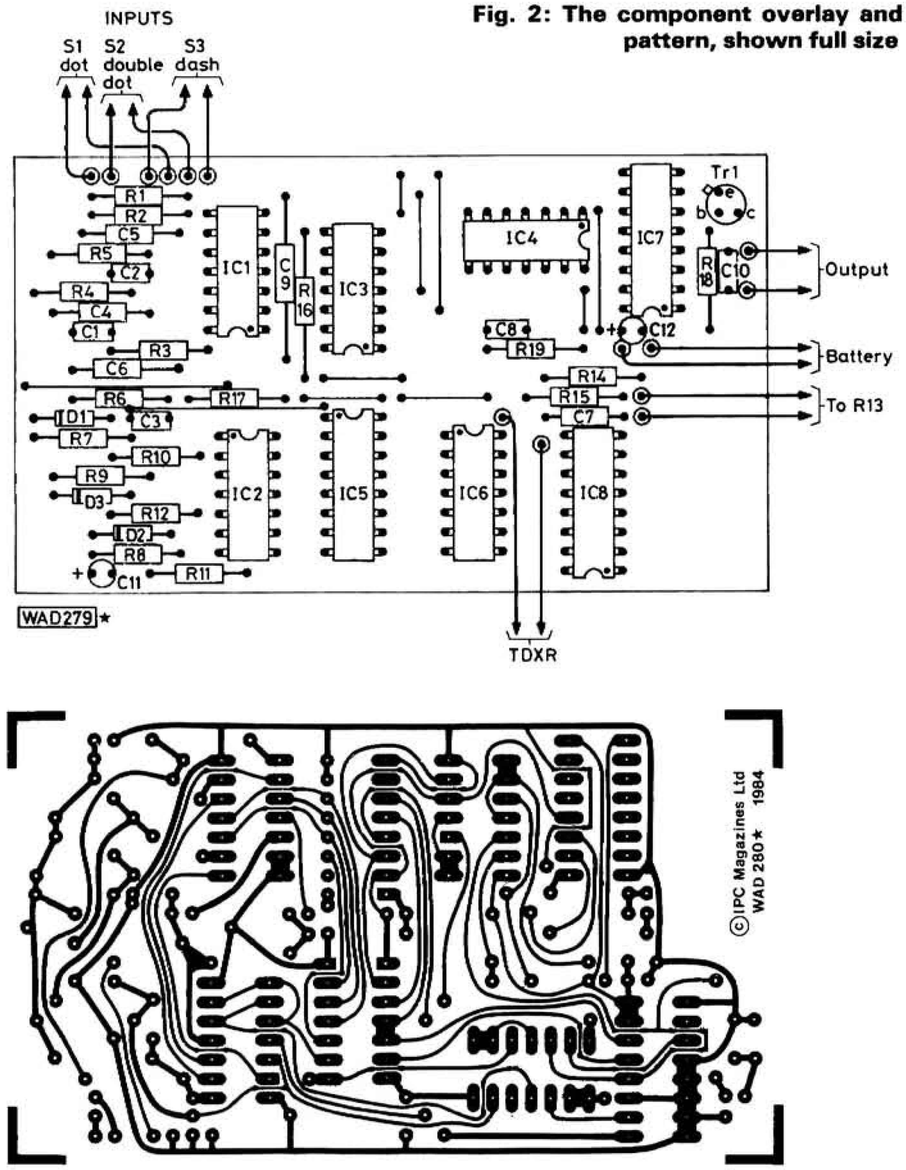


Fig. 2: The component overlay and p.c.b. track pattern, shown full size

Construction

To enable easy construction it was decided to design a single sided p.c.b. making things simple for home production or cheaper if you wish to buy out. The board was designed to fit a standard Bimbox size 113 × 63 × 31mm, although, of course, any suitable enclosure may be used.

Once the components have been collected together, assembly is very straight forward and it shouldn't take longer than the odd rainy weekend to complete. Observation of the usual c.m.o.s. handling instructions and the use of a pencil point soldering iron are strongly recommended.

The only really tedious bit of work seems to be cutting three square holes in the plastics box for the keyboard switches. These can be cut either along one edge of the box or in the bottom, forming the "portable" or "desk" model respectively. The former option fits more easily into the pocket and is convenient for portable or hand-held operation; the latter may be preferable if the keyer is to be located on a horizontal surface in front of the rig or on the chair arm. Three more holes—one for the speed control/on-off switch, one for the output jack socket and a small one for the piezo-electric transducer complete the drilling and hacking. A thin metal strip was bent up to form a clip for the battery and was securely attached to the bottom of the box with double sided sticky tape. This tape proved very powerful and was also used to attach the transducer; it would also be good enough to locate the battery itself if you didn't wish to bother with making the clip.

All the switches etc. are fitted into the box first and then connected by flying leads to the assembled printed circuit board which after removing the two corners indicated lies neatly (components downwards) just underneath the lid of the box. There's enough room for a small side-tone switch etc. if you want the optional extras.

Points to notice when assembling the components on the p.c.b. are that capacitors C4, C5 and C6 should be inserted last so that they have room to spread over the top of adjacent components since their width may be a little large. The output speed potentiometer is wired so that clockwise rotation reduces the speed to present a more uniformly graduated scale.

Logic Flow Description

A key depression causes a change from high to low level at the input pulse generator. A simple *CR* circuit differentiates the level change to produce a pulse fed to the f.i.f.o. data input via an OR gate. All data input pulses are ORed to make the f.i.f.o. input load pulse (f.i.f.o. loaded with low to high going edge). Up to 16 sequential entries can be loaded into the f.i.f.o.

The loaded pulses pass through the f.i.f.o. to the appropriate data output pins and produce a high level on Data Output Ready. This output is taken to the asynchronous parallel load of the Output Shift Register (o.s.r.) where an encoded version (Morse) of the f.i.f.o. outputs is loaded.

Loading the o.s.r. causes the o.s.r. Empty signals to go low. A delayed version of this signal is used to remove the o.s.r. parallel load, remove the data from the f.i.f.o. and start the output clock.

Morse code is shifted serially from the o.s.r. at a rate determined by the setting of the clock speed (R13). The serial output is fed to an output stage and also to a side tone generator.

When the o.s.r. again becomes empty, the delayed empty signal is removed from the o.s.r. force parallel inputs load to enable transfer of the next data from the f.i.f.o.

If the f.i.f.o. itself has become empty after the last o.s.r. load, the f.i.f.o. reload pulse will be enabled and if keys still remain pressed a f.i.f.o. reload for the appropriate key will take place. This action will follow through to the o.s.r. as before after a negligible delay. If both single dot and dash keys remain depressed, the Iambic feedback will cause alternate dots and dashes to be reloaded.

Key to Schematic Diagram

Key Input Circuits: This serves two functions a) to produce a pulse for entry to the f.i.f.o., b) to produce a level to gate the f.i.f.o. reload pulse.
Reload Input Gates: Gates the f.i.f.o. reload pulse with the key input level qualified by "Iambic mode feedback" level.
FIFO Input OR: Passes the key input or the output from the reload gates to the f.i.f.o. data inputs and to the f.i.f.o. input load.

Table 1

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

★ components

Resistors
¼W 5% carbon film

10Ω	3	R1–3
6·8kΩ	1	R18
10kΩ	5	R10–12, 14, 17
22kΩ	7	R4–9, 16
47kΩ	2	R15, 17

Potentiometer, with switch

220kΩ (log)	1	R13

Capacitors
Monolithic ceramic

10nF	1	C8
0·1µF	4	C1–3, 10

Polystyrene

100pF	1	C7
220pF	1	C9
470pF	3	C4–6

Tantalum bead 16V

1µF	2	C11, 12

Semiconductors
Diodes

1N4148	3	D1–3

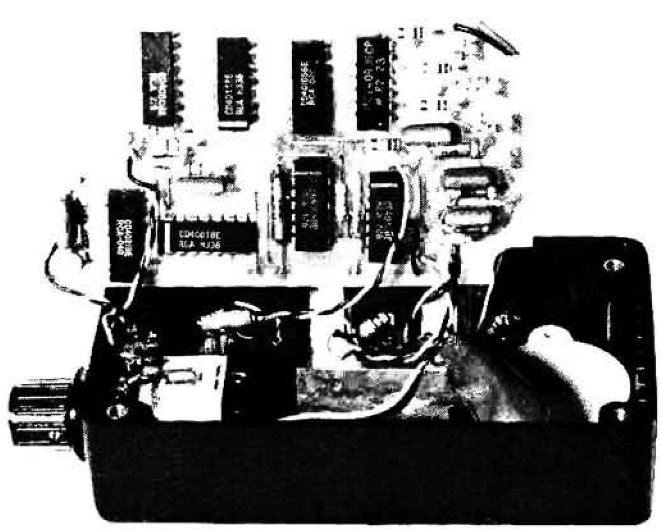
Transistors

Tr1	1	BC108

Integrated circuits

4001	1	IC4
4011	1	IC6
4021	1	IC7
4060	1	IC8
4075	2	IC1, 3
4093	1	IC2
40105	1	IC5

Miscellaneous
Toko PB2720 piezo-electric transducer; 3·5mm jack socket; key switches (3) Alps KCC10002; tops (3) KT2-1; Bimbox 2003 (113 × 63 × 31mm); 6-F22 (PP3) 9V battery; p.c.b.



The authors prototype Triambic Keyer

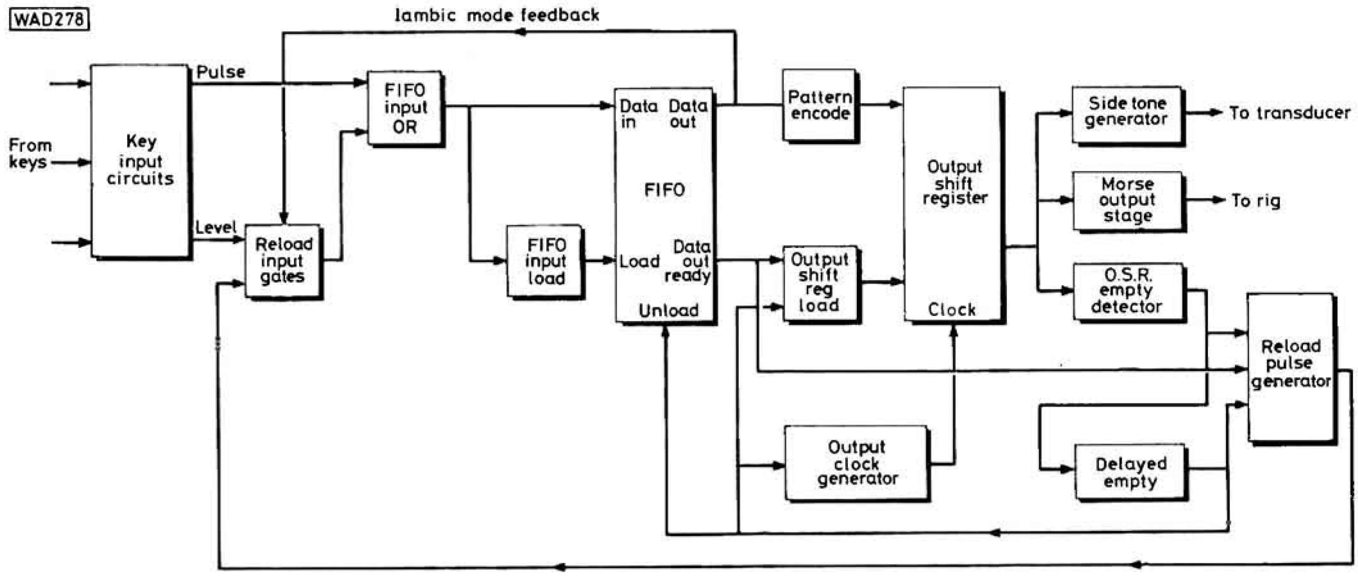


Fig. 3: Block schematic diagram of the Triambic Keyer

FIFO Input Load: Takes any f.i.f.o. data input pulse and generates a common f.i.f.o. loading pulse. The f.i.f.o. is loaded on the low to high going edge of this pulse.

FIFO: The action of the f.i.f.o. is to store the data inputs in the order received and present them to the data outputs in the same order, together with a "Data Output Ready" signal.

Sequential data outputs are "removed" by presenting a falling edge to the "Shift Out" pin of the f.i.f.o. This permits the next lot of data to appear at the outputs together with its "Data Output Ready" (if more data was available in its store).

When the f.i.f.o. becomes empty, the last data remains at the data outputs although of course the "Data Output Ready" signal still goes low to indicate that the data had been used.

Pattern Encode: The data stored in the f.i.f.o. shows which key has been pressed or is to be repeated. This is changed to a pattern corresponding to the Morse code for that key for presentation to the Output Shift Register.

Output Clock Generator: This circuit consists of an oscillator whose frequency is controlled by the variable resistor followed by a 14-stage binary counter/divider. The output—taken from the twelfth stage for convenience—makes shift pulses for the Output Shift Register at the "element" frequency of the Morse code to be produced. One element = 1 dot or 1/3 dash etc. The oscillator is enabled as long as the Output Shift Register is "not empty".

Output Shift Register Load: This logic controls the serial/asynchronous parallel pin of the Output Shift Register. When the f.i.f.o. Data Output Ready goes high, the encoded pattern is forced into the register. When this action is complete, a feedback from the "not empty" signal allows the Output Shift Register to revert to synchronous shift mode.

Output Shift Register: This is an 8-bit serial shift/asynchronous parallel load register. The register is parallel loaded asynchronously from the f.i.f.o. with a pattern corresponding to morse code i.e. with a high level for each output clock element (see Output Clock Generator) and a low level for each space element. Thus, the dash is loaded as high, high, high, followed by lows, and double dot as high, low, high, followed by lows. After being loaded, the register is switched into shift mode and the loaded pattern is shifted serially to the output. When all highs and one following low have been shifted out, the register will be reloaded from the f.i.f.o. if more data is available.

Output Shift Register Empty Detector: This circuit looks at two bits from the Output Shift Register to determine whether a pattern is currently loaded. The pattern always includes a single element space at the end so the detector indicates empty after that space has been shifted.

Delayed Empty: The Output Shift Register Empty signal is delayed by 2 to 3 microseconds to allow sufficient time for parallel loading the Output Shift Register and also for making the f.i.f.o. reload pulse.

Reload Pulse Generator: This pulse which feeds back to the f.i.f.o. Reload Input Gates is generated from the Empty and Delayed Empty signals and occurs at the point when the Output Shift Register becomes empty but only if the f.i.f.o. itself is also empty.

Iambic Mode Feedback: The f.i.f.o. output data indicating "single dot key" as the last output before going empty is used to inhibit the dot key reload pulse and enable the dash (and double dot) key reload pulse when both single dot and dash keys are held at the same time. This causes alternate dashes and dots to be reloaded.

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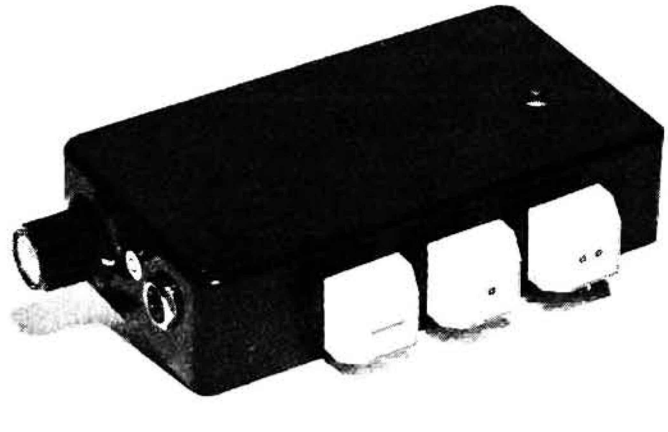

is really equivalent to reflection from a virtual reflecting boundary within the layer, hence the term "reflection" rather than refraction is used, so we speak of "reflection from a layer". However, as the frequency of a wave is increased it will penetrate further into the layer before being turned onto an earthward bound path. With continued increase in frequency the bending becomes less and the wave will tend to travel much further horizontally where the ionisation density is maximum before further bending allows it to make an exit from the layer. If the frequency is increased still further the wave will be only partially bent whilst in the region of maximum ionisation and will then travel on into outer space.

The foregoing is illustrated in Fig. 2.5 in which the paths of three waves of different frequency are shown with (a) being below the maximum frequency that can be reflected, (b) being equal to it and (c) being above it. The frequency of waves reflected to earth and those that pass through the layer are closely related to the degree of ionisation and it is from this that the terms "maximum useable frequency" (m.u.f.) and "critical frequency" are derived and which will be dealt with next month.

Acknowledgement

The author is indebted to Mr. G. W. Gardiner and Mr. R. W. Smith, Higher Scientific Officers of the World Data Centre for Solar-Terrestrial Physics at the Rutherford Appleton Laboratory, Chilton, Oxfordshire for providing historical information concerned with the discovery of the ionosphere as in Part 1, the ionograms illustrated in this article, data concerned with ionospheric radio wave propagation and for checking both Part 1 and Part 2 of this series.

Triambic Keyer

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Side Tone Generator: The output from the Output Shift Register enables an oscillator using two NAND gates for driving the side tone transducer.

Morse Output Stage: A single *npn* transistor (grounded emitter with open-collector output) is used to amplify the signal from the Output Shift Register to drive the keyer input of the rig. Since the battery is a floating power supply, rigs requiring positive or negative inputs can be driven directly but voltage and current specifications should be checked before connection.

Conclusion

The f.i.f.o. Morse sender is a keying device specifically designed to increase the pleasure of sending good c.w. In addition, it is rugged, self-contained, portable and inexpensive. Give it the "drop test" on field day or just relax in your favourite armchair and enjoy that c.w. QSO as never before. ●

1) *The Triambic Keyer* by M. B. Rhodes G4FMS. *Radio Communication* November 1982.

Useful Reading

SGS Databook COS/MOS B-Series Devices, 2nd Edition. March 1981.
The Key to Morse by A. Smith G4FAI. *Practical Wireless* October 1981.