AN RTTY PRIMER

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Part I

Here is the start of a step by step method to get you going in the fascinating world of radioteletype.

After twenty years of off-and-on amateur activity I discovered radioteletype. I imagine that I stayed away from the mode for all this time as a result of some rather strong prejudices and misconceptions. Ignorance was sire to my apprehensions.

I hope that I can ease similar skepticism that other amateurs are sure to have.

Radioteletype (RTTY) means just what the word says: *radio*—a "wireless" method of communication; *tele*—distance; *type*—type. RTTY is a wireless method of communication whose end result is printed messages. The originator types his message on a typewriter-like device. It is then sent over the air via his transmitting system, whereupon it is automatically typed, in final readable form on the recipient's typewriter-like device.

The sequence of mechanical and electronic events between the signal originator's touch of his typing key and the signal recipient's machine printing the corresponding character is neither difficult to understand nor overly involved to reproduce in your own shack.

Radioteletype signals are transmitted in the form of electronic pulses in much the same way as a c.w. signal is. However, the similarity between the two modes ends very quickly. Morse Code is comprehended by amateurs because they are human. There are, of course, quite sophisticated circuits bandying about which can transmute the dits and dahs of Morse to either printed copy or video displays, but in the last analysis, nothing beats the human hearing mechanism for copying the code, especially if it is "down in the mud" and hard to understand.

To better understand the pulsed code used for RTTY it is wise to completely understand the pulsed code we use for c.w.

In Morse Code each letter, number and punctuation mark is represented by a different sequence of short pulses, long pulses and spaces. In point of fact, there are three different lengths of spaces used: the one between the dits and/or dahs of the individual character, the one between the characters themselves and the one between words. In all, c.w. fans have to keep in mind five different lengths of pulses and/or spaces in order to use the code.

In addition, each character, for the most part, consumes a different amount of time for its transmission (the reason for the "for the most part" is that, for example, the letter "b" (dah-dit-dit-dit) and the letter "v" (dit-dit-dit-dah) require the same absolute amount of time, one letter being the Morse mirror image of the other. But the generality of this occurrence is not the case since there are only six such pairs of letters).

Let's take a microscopic view of the Morse Code using the words "RTTY is fun." If we use the length of the dit as the unit from which all other lengths are derived, it will be seen that a dah is three dits long, the space between the dits and/or dahs in a single letter is one dit long, the space between letters is three dits long, and the space between words is five dits long. See fig. 1.

The Morse Code thus produced is deliberate and textbook. If we all sent like that, your fist would sound no different from mine nor anybody else's.

After having examined the Morse Code with an eye toward its character-to-character time-duration differences, it becomes clear that, for copying, a machine, which is a very time-consistent device, cannot hold a stick to the human ear-brain. Since a machine works on such time-invariant principles (for example, 420 revolutions per minute) it is necessary to mold the code to the machine's uniformity of operation. A code which is time-invariant vis-a-vis character length would do the trick.

The Murray Code is a pulsed code the length of whose character representations is time-invariant, that is, the sequence of pulses for one character takes as much time to be sent as the sequence of pulses for any other character.

The Murray Code, like the Morse Code, consists of a series of on-pulses and off-pulses. The on-pulses are called "marks" and the off-pulses are called "spaces."

Each character is a combination of five marks and/or spaces. Consider the case where the unit length of the code (one mark or one space) is 22 microseconds long. Each character, regardless of its nature (alphabetic, numeric or punctuation mark), will have a time duration of 110 microseconds.

Referring to the illustration, fig. 2, the part of the square wave above the horizontal time axis represents the mark pulse and the part of the square wave lying below the axis represents the space pulse. The letter "F" is Murray-encoded by the

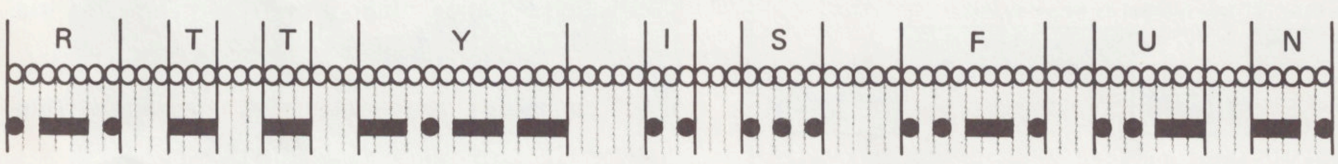


Fig. 1—RTTY timing sequence compared to standard c.w. spacing

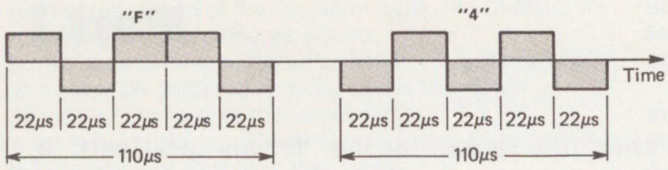


Fig. 2—Timing sequence of the Murray Code.

sequence *mark-space-mark-mark-space* and the number "4" is encoded by the sequence *space-mark-space-mark-space.* The complete encoding scheme for the Murray Code is shown in Table I.

Note that a total of 32 possible combinations of mark and/or space can be used. Each pulse has either a mark or space possibility and since there are five different pulses per character, $2^5 = 32$ combinations exist. This number is inadequate for the 26 letters of the alphabet, the ten numerals and the several punctuation marks. However, the RTTY machine can be made to shift by using a system analogous to, but not mechanically the same as, the shifting scheme of an ordinary typewriter.

There are some "non-printing" keyboard operations also. Among these are keys for *letters shift*, *figures shift*, *carriage return*, *line feed* and *blank.*

Unlike an ordinary typewriter, the teleprinter must be told each and every time it is to go from printing alphabetic characters to numeric characters, and *vice versa.* A typewriter "unshifts" when the shift key is let go. This is not the case with a teleprinter; hence, the necessity for separate "letters" and "figures" shifts.

We now have a code, the lengths of whose characters is constant and is therefore compatable with machines for transmission and reception.

The electro-mechanical method used for the transmission of RTTY is not, however, of the off/on type. Unlike c.w. where the carrier is interrupted (key up) for space and the carrier is transmitted (key down) for mark, the RTTY signal is sent under constant carrier (100% duty cycle) conditions. There are two commonly used methods for transmitting the mark and space of the Murray Code under this constant carrier condition, see fig. 3. Both involve the shifting of audio frequency tones. In one method (frequency shift keying or FSK) the carrier, with a beat frequency injected at the receiver, changes frequency; in the other method (audio frequency shift keying or AFSK) two tones of different audio frequency modulate a steady carrier and thus effect a frequency change by alternating from one tone (for the mark) to the other

NOTE:
The letter "F" tone encoded for frequency shift.

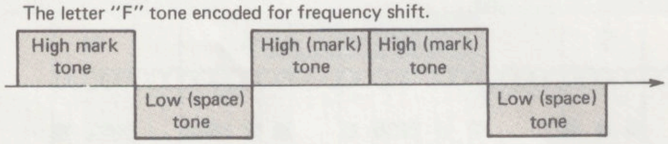


Fig. 3—Transmitting the mark and space of the Murray Code.

tone (for the space). For the sake of simplicity and convenience this discussion will assume that the higher tone represents the mark and the lower tone represents the space (although this is not always the case in the actual transmission of RTTY signals).

There are two fundamental considerations with reference to shift keying (FSK or AFSK). These are (1) the desired r.f. frequency of transmission and (2) the number of Hertz separating the mark tone from the space tone (the frequency shift). Item (1) is largely at the discretion of the individual amateur, while item (2) is pretty well standardized within the amateur RTTY community. Typical frequency shifts used are 170 Hz. and 850 Hz., with the former being the most popular among amateurs, see fig. 4.

Regardless of the keying method used—the advantages and disadvantages of each will be discussed later—three basic pieces of equipment are needed for two-way communications. Since it is assumed that the reader already has in his possession a transmitter/receiver, only two other specialized units are necessary for the transmission and reception of radioteletype signals. These are the keyboard-teleprinter combination and the demodulator (also called the terminal unit, TU, or converter).

The teleprinter (Teletype® is a registered trade name) is an electro-mechanical device for encoding and decoding the Murray Code. It also prints messages on a piece of paper. There are many types of teleprinters available to the amateur, ranging in price from the cost of picking it up (free) to many hundreds of dollars. Teleprinters and related mechanical equipment will be discussed at greater length in a subsequent article.

The demodulator is an electronic device which converts the mark and space RTTY tones sent over the air into d.c. pulses which are understood and transmuted by the teleprinter into printed characters. There are many types of demodulators. These, too, will be discussed at a later time.

The sequence of events for the transmission and reception of RTTY signals is, therefore, as follows:

(1) depressing a key on the teleprinter keyboard
(2) mechanically encoding the Murray Code equivalent of the character via the teleprinter
(3) transmission of the encodement, via a transmitter, using one of the two frequency shift methods
(4) receipt of the r.f. tone encoded signal in one's receiver
(5) demodulation (changing to dc pulses) of the RTTY tones in the converter
(6) transmutation of the d.c. (Murray encoded) pulses by the recipient's teleprinter. This gives the final printed copy.

The basic RTTY station, with the signal path indicated is shown in fig. 5.

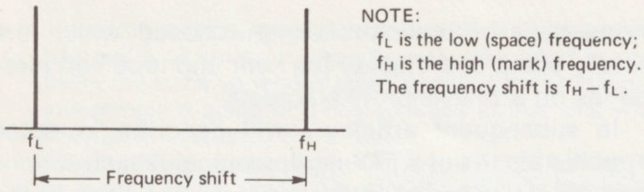


Fig. 4—Illustration of the frequency shift.

Note that each box in the diagram does not necessarily represent a different piece of equipment sitting on your operating table. For example, the demodulator and shift keyer can be housed within the same cabinet; so can the printer and keyboard; so can the transmitter and receiver if one uses a transceiver.

With the fundamental RTTY station setup in mind we are now in a position to look at some variations on the theme.

The spectrum of mechanical radioteletype equipment is quite broad. Much of the basic gear and many intriguing accessories are more readily available than one might think. And (here is the best part) quite cheap to boot. Of course, as any amateur worth his mettle knows, it is very possible to spend next month's rent and food money on a fascinating piece of equipment but that is neither necessary nor, interestingly enough, desirable when wetting your feet in RTTY. The best education and most convincing arguments in this regard are found in buy and sell ads in the various amateur publications. It is quite possible to set up a teletype station for a surprisingly small amount of cash.

Now to take a look at some of the auxilliary goodies available to amateurs.

Usually the first two pieces of gear that most RTTYers get are the typing reperferator ("reperf") and the transmitter-distributor ("TD"). These devices, completely compatible with the teleprinter, allow the storage and automatic retransmission of Murray encoded messages on a piece of paper tape. With these two machines one has the capability of preparing messages for transmission while simultaneously and independently printing a received message on the printer. When the message on the printer is complete and the other amateur turns it

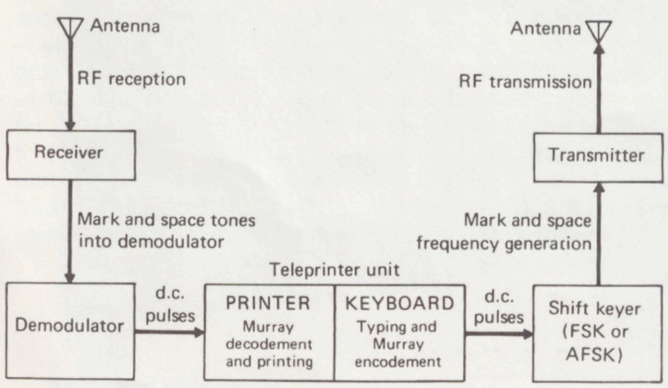


Fig. 5—The basic RTTY station.

THE MURRAY CODE
(Upper-case characters may vary
from machine to machine)

UPPER CASE	LOWER CASE	ELEMENTS 1	2	3	4	5
—	A	M	M	S	S	S
?	B	M	S	S	M	M
:	C	S	M	M	M	S
$	D	M	S	S	M	S
3	E	M	S	S	S	S
!	F	M	S	M	M	S
&	G	S	M	S	M	M
#	H	S	S	M	S	M
8	I	S	M	M	S	S
'	J	M	M	S	M	S
(	K	M	M	M	M	S
)	L	S	M	S	S	M
.	M	S	S	M	M	M
,	N	S	S	M	M	S
9	O	S	S	S	M	M
0	P	S	M	M	S	M
1	Q	M	M	M	S	M
4	R	S	M	S	M	S
Bell	S	M	S	M	S	S
5	T	S	S	S	S	M
7	U	M	M	M	S	S
;	V	S	M	M	M	M
2	W	M	M	S	S	M
/	X	M	S	M	M	M
6	Y	M	S	M	S	M
"	Z	M	S	S	S	M
Letters		M	M	M	M	M
Figures		M	M	S	M	M
Space		S	S	M	S	S
Carriage Return		S	S	S	M	S
Line Feed		S	M	S	S	S
Blank		S	S	S	S	S

M represents "mark"
S represents "space"

Table 1—The Murray Code.

over to you, you merely turn on the TD and the message you prepared gets sent over the air automatically—at a speed of 60 words per minute (or 75 w.p.m. or 100 w.p.m. depending on the specific equipment).

Messages, CQs, tapes describing your station ("brag tapes"), test tapes, tapes of pictures (there are some **very** talented amateur artists out there who can create virtual masterpieces out of printed characters—more on this later), tapes of complete conversations—the list is as long as your imagination—can be punched on tape, stored and played back at your leisure. The reperf and TD are, to some amateurs, an absolute necessity.

There are paper winders and tape winders (so the floor of the shack doesn't become covered with paper); there are automatic CQ callers, automatic station identifiers, devices which send out your message at a steady rate regardless of how slowly you type (even a hunt-and-peck typist can be a crackerjack RTTY-er); there are tuning display systems, both metered and 'scoped; and, most intriguing of all, there is silent, video radioteletype.

Video RTTY is the up and coming thing now. This does not mean, incidentally, that the mechanical method is outmoded or anywhere near it. It simply means that there are systems that can be either home-built or commercially purchased which are totally silent and display the sent and received messages on a television-like screen.

In subsequent articles I will describe in detail specific pieces of RTTY equipment, give instructions and diagrams for building and installing each of the three basic units needed for a RTTY station, talk about theory, and, most important to the newcomer, give step-by-step, deliberate and *simple* directions so that your odyssey into the world of RTTY is as painless and enjoyable as possible.

Part II

In Part II of An RTTY Primer, Irwin Schwartz goes into how RTTY characters are generated and received.

The primary concern of communications engineers is improvement of reliability. In this regard the most significant problems encountered by designers of receivers are those related to increasing the sensitivity and selectivity while simultaneously increasing the signal-to-noise ratio.

It is possible, however, to improve reliability of communications by means other than tampering with receiver design. Such improvement can be realized by changing the *mode of transmission* of the signal. To illustrate this point, consider the problems encountered while copying a c.w. signal off the air. If a c.w. signal fades into the mud or if another c.w. signal zero-beats the one being read, copying is, at best, difficult and, very often, impossible.

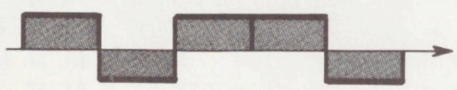


Fig. 1—The Murray encodement of the letter "F".

Under marginal conditions frequency shift keying (FSK) has advantages over c.w. With FSK two tones are transmitted rather than one. In a sense, FSK may be thought of as two separate and distinct c.w. signals transmitted on two separate and distinct frequencies (the difference between which frequencies is the *frequency shift).* Independent of receiving conditions, signal-to-noise ratio notwithstanding, the demodulator will get a double dose of information, so to speak.

To illustrate the point recall that the Murray encodement for the letter "F" can be diagrammed as in fig. 1:

Translated into audio tones the letter "F" would sound like "high tone/low tone/high tone/high tone/low tone."

However, the same information may be transmitted in two other ways:

(1) high tone/no tone/high tone/high tone/no tone (Figure 2).

(2) no tone/low tone /no tone/no tone/low tone (Figure 3).

The above two ways of sending the letter "F" may sound like c.w. but are not, of course, Murray-encoded. The signal may be thought of as being sent in "abbreviated Murray," that is, high tone (mark) only or low tone (space) only.

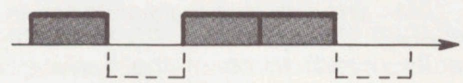


Fig. 2—The letter "F"—mark only.

There are then three ways an FSK signal can be sent and/or received—mark only, space only, and both tones. If a converter is designed which would react to any one of the three possibilities we could compensate for some of the effects of QRM (for example, a c.w. signal zero-beat with one of the tones, in which case the converter copies the other tone), and in theory, improve the signal-to-noise ratio at the receiver output.

All state-of-the art demodulators have the capability of performing under the three possible FSK tone configurations.

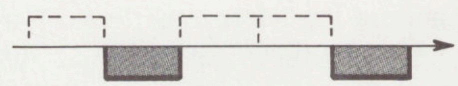


Fig. 3—The letter "F"—space only.

A demodulator (converter, terminal unit, TU) has one major function: to change the incoming RTTY signal into d.c. pulses. The d.c. pulses, in turn, activate ("key") the selector magnets housed in the teleprinter which then move the corresponding typing hammers to give printed copy.

The converter must respond only to the mark and space audio tones at the receiver's output and to *nothing else*—not c.w., not a.m., not s.s.b., not noise pulses—*nothing else.* Specifically, the tones to which we want the TU to respond are the standard amateur RTTY tones of 2125 Hz for space and 2295 Hz for mark (this is 170 Hz shift); if 850 Hz shift is used (it is virtually obsolete on the amateur bands) the audio tones would be 2125 Hz for space and 2975 Hz for mark. The converter, then, must discriminate

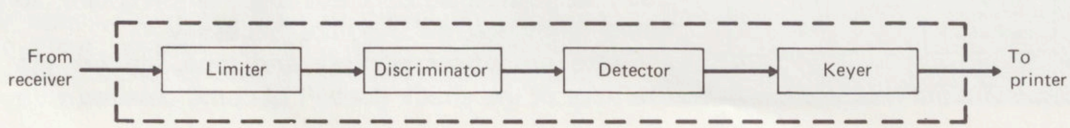


Fig. 4—Block diagram of a basic Demodulator.

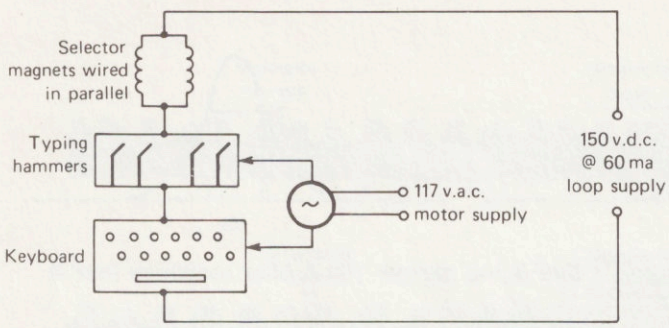


Fig. 5—Supplying power to a Teleprinter.

in favor of 2125 Hz and 2295 Hz (or 2975 Hz) and disregard everything else. The stage of the TU which performs the function of tone discrimination is called, not surprisingly, the **discriminator.**

Control of the amplitude ("loudness") of the two tones as they go through the demodulator is also desirable, whereby (1) they always have the same amplitude and (2) the amplitudes neither exceed nor fall below a predetermined level. This function offsets the effects of the "selective fading" problem where one of the tones QSB's out independently of the other. The stage which performs the task of amplitude control is called a **limiter.** If the amplitude falls below a certain level, the signal is amplified; if the amplitude exceeds a certain level, the signal is clipped or attenuated. In a properly balanced limiter the mark voltage is always equal to the space voltage and the selective fading problem is thereby overcome.

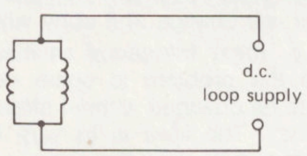


Fig. 6—Selector magnets wired in parallel (60 ma).

A **detector** (rectifier) stage is needed to change the input signal into d.c. pulses for keying the selector magnets. The detector can be as simple as a germanium diode or as complex as those used in sophisticated f.m. receivers. Of course the detector's d.c. output will have to be filtered to eliminate any residual ripple.

Fig. 4 shows a block diagram of a basic demodulator.

The only stage of the converter not yet touched on is the **keyer.** A description of the keyer's function will be instructive in understanding the relationship between the demodulator and the teleprinter.

The keyer of a converter serves as a switch, activating the selector magnets of the printer with the right voltages at the right time. A keyer can be a relay, a vacuum tube or solid state. Relays and tubes present well known problems, i.e., relays develop dirty contacts and tubes get hot.

The keyer is the connecting link between the electronics of the demodulator and the mechanics of the teleprinter.

A teleprinter incorporates two machines run by a com-

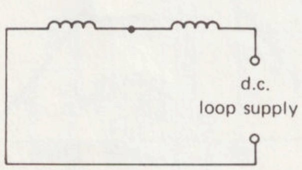


Fig. 7—Selector magnets wired in series (20 ma).

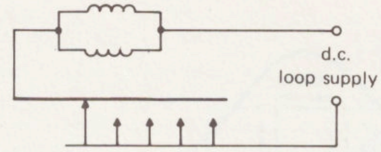


Fig. 8—Mark hold.

mon motor. The typing and printing mechanisms are not connected physically but are tied together through an electrical circuit called a **loop.** There are thus *two* supplies needed to power a teleprinter: an a.c. supply for the motor and a d.c. loop supply for the printing and keyboard selector magnets. The motor supply is rated for 117 volts a.c.; the d.c. supply for about 150 volts d.c. Both are usually built into the teleprinter case. See fig. 5.

In most cases the selector magnets are wired in series with the keyboard, both being powered by the loop supply.

All machines have a pair of selector magnets. If the two selector magnets are wired in parallel (fig. 6) the current drain on the loop supply will be about 60 ma. If the magnets are wired in series (fig. 7) the drain is about 20 ma. The usual practice is to wire them in parallel.

Notice that in fig. 8 the schematic symbol for the keyboard has five arrows pointing upward, only one of which is in contact with the loop supply circuit. Electrically this means that in "rest" position the keyboard keeps the loop circuit closed and current is drawn from the supply. This condition is called **mark hold.**

By moving the five keyboard contacts in an appropriately timed sequence it is easy to see how characters can be

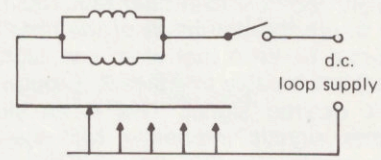


Fig. 9—Using a s.p.s.t. switch to key a loop supply.

Murray encoded (or decoded) by making and breaking (marking and spacing) the contacts, thereby impulsing the selector magnets and pulling the corresponding characters' hammers.

In lieu of the keyboard a single pole-single throw switch can be interposed, realizing the same effect. See fig. 9.

Since the keyboard is already in mark hold, the switch can assume the make-and-break function. If the switch is opened and closed vis-a-vis the Murray code for time durations in accord with the speed of the machine (say 60 words per minute) the printer will function as if it were being activated by the keyboard.

The keyer stage of the demodulator *is* that switch. It should now be clear how the receiver, the converter and the teleprinter are interconnected. Fig. 10 illustrates the point.

Special consideration must be given to the station's

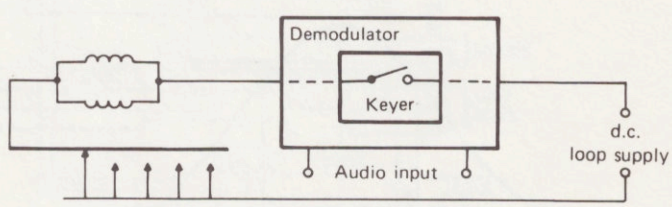


Fig. 10—Using the keyer stage of a demodulator to key a loop supply.

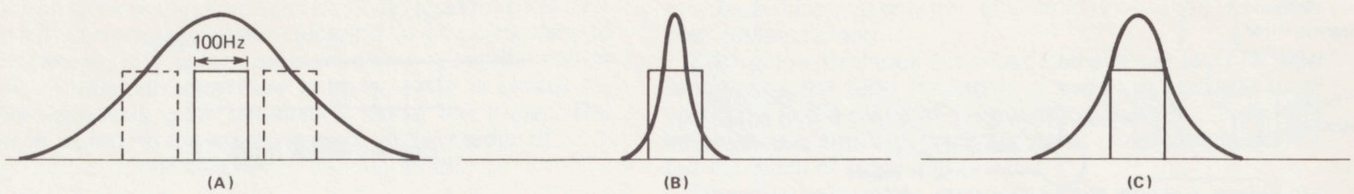


Fig. 11—(A) A filter response that is too wide. (B) a filter response that is too narrow. (C) A filter response that is just right.

receiver since, as will soon become obvious, the nature of an RTTY signal dictates a bit more specialization in reception technique than is required for c.w. or single sideband. We can get a glimpse into the problems by looking at how a receiver reacts to signals in general.

Consider a continuous key-down c.w. signal. In order for this signal to be processed by the receiver it must go through a "door" called a bandpass filter. If the response of the filter is too narrow, the signal will not pass through; if the response of the filter is too wide the signal will pass through but so will other, generally undesired, signals. The most effective bandpass filters, then, for a c.w. signal are those whose bandwidths are exactly the same as the bandwidth of the c.w. signal itself. (The existence of such filters is, of course, an exaggeration. A filter can never fit a signal exactly).

Consider now a c.w. signal whose bandwidth is 100 Hz. Fig. 11 shows the effects on such a signal for a filter too narrow, a filter too wide, and a filter that "fits" the signal.

In the case where the bandpass of the filter is too wide (fig. 11(A)) it can be seen that other c.w. signals (shown by broken lines) will be able to squeeze through the "door" along with the desired signal. This is an illustration of QRM, i.e., other signals interfering with the one being read. As every amateur knows, this can ruin a QSO.

In the next case (fig. 11(B)) the filter is too narrow. Not enough of the signal gets into the receiver and copy likewise becomes difficult (c.w. men pay the price for a super-narrow filter by listening to it "ring"). Choice (B) is therefore undesirable.

Choice (C) solves each of the aforementioned problems. The filter passband is wide enough to pass the complete bandwidth of the signal, yet narrow enough to reject all signals on either side of its passband.

In single sideband the signal passes most effectively through a filter whose bandwidth is in the order of 2400 Hz —much wider than that for a c.w. signal. To discover the role a bandpass filter plays listen to c.w. with the receiver in its single sideband position. If the band is crowded quite a few signals will be heard; then switch to the c.w. position. The number of signals heard will be dramatically reduced.

RTTY signals have unique reception problems. Two considerations are necessary for understanding the situation. In addition to the filter bandwidth (which must allow the signal to pass) it is also important that as the signals pass through they appear at the receiver's output at frequencies of 2125 Hz and 2295 Hz (or 2975 Hz). This may not always happen.

Consider a 170 Hz shift RTTY signal. Two tones of 2125 Hz and 2295 Hz must pass through a filter in the receiver. If the center frequency of the filter's bandpass lies exactly at the center of the two RTTY tones, i.e., at 2210 Hz, *and* the filter's bandwidth is 170 Hz (fig. 12), then the receiver will perform optimally. Both tones will pass and the TU will respond. If, however, the center frequency of the filter is not 2210 Hz. but, say 2500 Hz, one of the RTTY tones will not pass, even if the filter's bandwidth is still 170 Hz. This condition appears in fig. 13.

If the dial on the receiver is moved to compensate for a misplaced center filter frequency the frequencies of the RTTY audio tones will change and copy will be lost.

A variable b.f.o. (beat frequency oscillator) in the receiver can solve the problem to some degree since it allows the tones to be changed without affecting the center passband frequency. The idea is to vary the b.f.o. until both tones are passed through the filter.

Unfortunately, some receivers do not have a variable b.f.o. To rectify this situation a slight modification will have to be made on the receiver. I made such a change in my TS-520 (one 1" wire was added) and it works like a charm. Since every receiver will require its own particular modification (not all receivers have passband filters with the same center frequency characteristics) it will be necessary to obtain information for your particular one. I suggest that you write (and subscribe) to *RTTY Journal*, P.O. Box 837, Royal Oak, MI 48068 for specific data. Incidentally, some receivers, for example, the Drake R4-B, need no changes at all.

The next article will discuss demodulator operation in a bit more detail and will describe the construction of a simple converter.

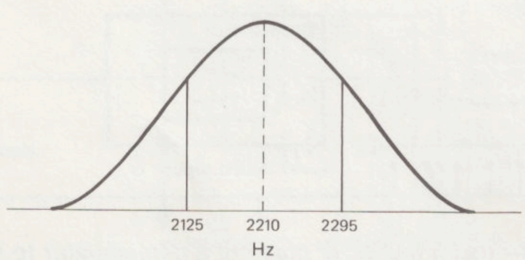


Fig. 12—Center filter bandpass frequency satisfactory for reception of 170 Hz RTTY. Both tones will pass.

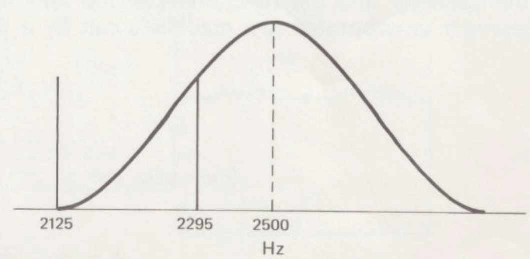


Fig. 13—Center filter bandpass frequency not satisfactory for reception of 170 Hz RTTY. Only one tone passes.

Part III of this engrossing series deals with the demodulator and its function and concludes with construction details for building your own.

Part III

An RTTY signal is distinguished in that it is two very rapidly changing frequencies separated by a small number of Hertz (usually 170). The function of a *demodulator* is to process these two discrete frequencies into d.c. pulses which will subsequently activate the selector magnets in the teleprinter.

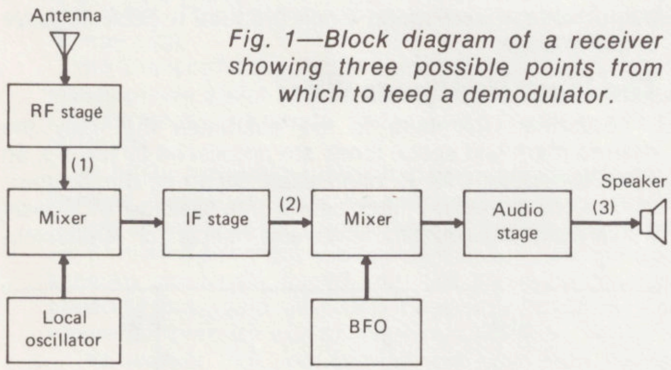


Fig. 1—Block diagram of a receiver showing three possible points from which to feed a demodulator.

If the signal path through a receiver is traced, it can be seen that there are several sources from which an RTTY signal can be fed into a TU.

Referring to fig. 1 consider the RTTY signal characteristics at each of the following three points: (1) after the r.f. stage, (2) after the i.f. stage, and (3) after the audio stage.

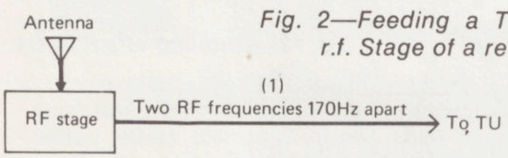


Fig. 2—Feeding a TU from the r.f. Stage of a receiver.

If the RTTY signal is fed into the converter from point (1), the signal source is effectively a truncated receiver as illustrated in fig. 2. This receiver has only an r.f. stage. If fed from here the TU must respond to two r.f. frequencies 170 Hertz apart. This is not easy to accomplish: for if such were the requirement, the TU's overall domain of response (its bandwidth) would have to be made *very* broad (on 20 meters in the order of 200 kHz) and, as a collateral undesirability, the TU would react to *every* signal in that spectrum. It would therefore be quite ineffective for a TU to respond to RTTY signals at their original transmitted frequencies.

At point (2) the r.f. signal has been mixed down to some intermediate frequency (in many receivers, 455 kHz). If this were the feedpoint the receiver would look as in fig. 3. This system is in use — some surplus gear use it — but it presents inherent design problems which are not so easily overcome.

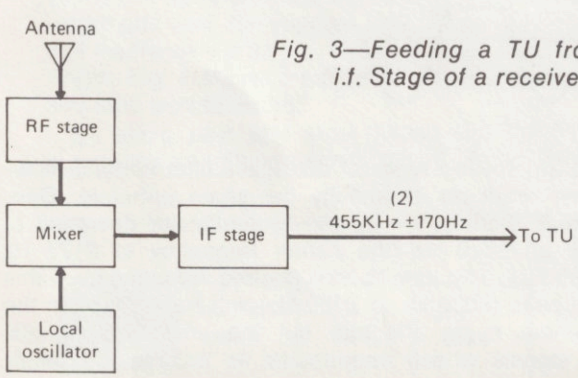


Fig. 3—Feeding a TU from the i.f. Stage of a receiver.

Thus, point (3) remains from which to feed the TU. At this point the i.f. signal has been mixed down again, this time to audio frequency, at which the receiver issues tones of 2125 Hz and 2295 Hz. The broad bandwidth problem of r.f. injection is avoided as are the design difficulties of i.f. injection.

In order to optimize the performance of a converter, it must be guaranteed that the two prescribed audio tones and *nothing else* pass through the demodulator. Each stage of the TU contributes to that end.

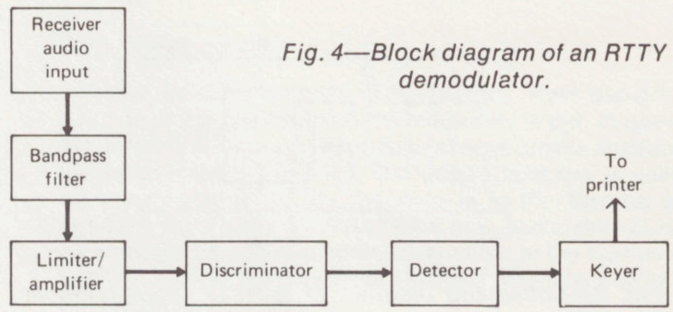


Fig. 4—Block diagram of an RTTY demodulator.

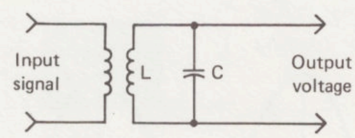


Fig. 5—Parallel-tuned L-C circuit used as a frequency discriminator.

Figure 4 is a block diagram of a demodulator which maximizes the possibility of processing the desired audio tones only. It should be pointed out that this demodulator contains complexities not always necessary for satisfactory reception.

The stages will not be discussed in the order they appear in the diagram since their interrelationships and functions can be seen more clearly if they are studied in a somewhat inside-out order.

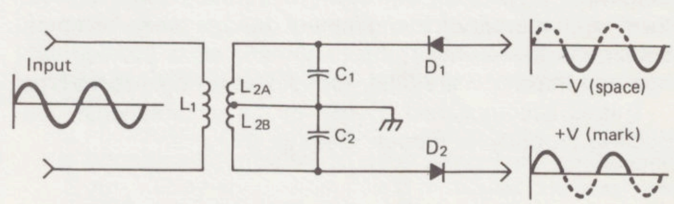


Fig. 6—A simple diode discriminator maximizing positive voltage for Mark *and maximizing negative voltage for* Space.

The Discriminator

For this stage and for the remainder of the article it will be assumed that narrow (170 Hz) shift is used where the low tone *(space)* is 2125 Hz and the high tone *(mark)* is 2295 Hz.

A frequency discriminator is a circuit whose output voltage is dependent on the frequency of the input signal. The simplest type of discriminator is a parallel tuned L-C circuit. See fig. 5.

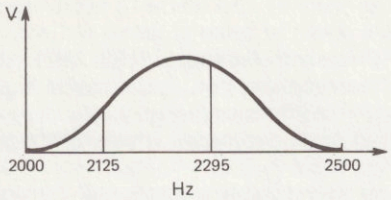


Fig. 7—Input bandpass filter characteristics.

The output voltage of this circuit is a function of the input signal frequency. Maximum output voltage is realized when the input signal frequency is equal to the resonant frequency of the L-C circuit. The resonant frequency f_r of

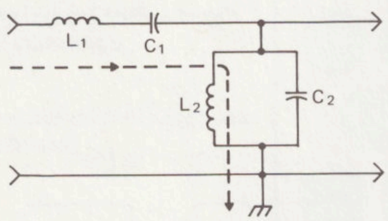
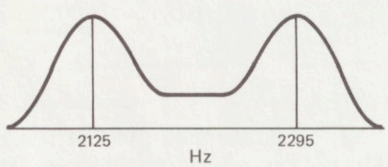


Fig. 8—Schematic diagram of a RTTY input bandpass filter. The broken lines show the paths of the undesired signals, i.e., High-Z through L1-C1 and Low-Z through L2-C2.

Fig. 9—Notch filter response curve.



an L-C circuit is related to the values of L and C by $f_r = \frac{1}{2\pi\sqrt{LC}}$, where L is the inductance in Henries and C is the capacitance in Farads. Two such tuned circuits are required for an RTTY discriminator — one which resonates at 2125 Hz and one which resonates at 2295 Hz.

However, it is undesirable for the resonance output voltages of the two circuits to be the same. For if such were the case the teleprinter could not disinguish between a mark and a space. Some method of maximizing both voltages while maintaining a differentiation between them is necessary. The simplest (and a very common) solution is to maximize one (say mark) as a positive voltage and maximize the other (space) as a negative voltage.

This is accomplished by use of the unidirectional conducting property of diodes. See fig. 6.

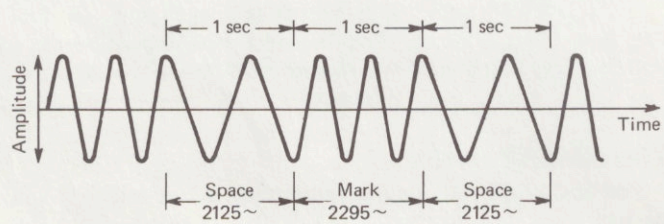


Fig. 10—RTTY signal as a frequency modulated signal.

Here, L_1 is a coupling link. Its only function is to introduce the signal into the discriminator. L_{2A} resonates with C_1 at 2125 Hz; L_{2B} resonates with C_2 at 2295 Hz. When a mark is received, the lower tuned circuit resonates and the positive half of the sinusoidal input signal voltage is conducted through diode D_2, the negative half being clipped by D_2's one-way conduction property. When a space is received, the upper tuned circuit resonates and the negative half of the sinusoidal input signal voltage is conducted through diode D_1, the positive half being clipped by D_1's one way conduction property.

Thus the end result of RTTY frequency discrimination in the example is that mark tones produce a peak positive output voltage and space tones produce a peak negative output voltage.

The Input Bandpass Filter

To further contribute to the guarantee that only the desired mark and space tones are processed by the TU, an *input bandpass filter* is often used ahead of the discriminator. The bandpass filter allows the passage of signals within desired frequency limits and rejects (or attenuates)

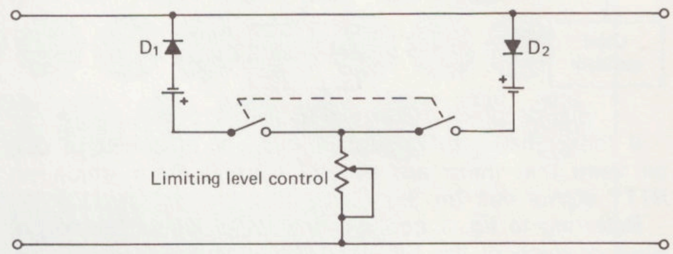


Fig. 11—Simple diode limiter.

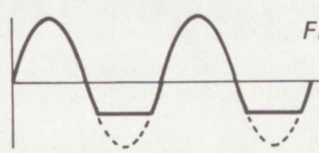


Fig. 12—Clipping effect of D1.

signals outside these limits. If the range of frequencies entering the discriminator is limited to, say, between 2000 Hz and 2500 Hz, the 2125 Hz and the 2295 Hz tones will pass and mostly all other signals will be rejected or, at least to a large extent, eliminated.

Figure 7 shows a picture of what is required. The filter whose response is shown will pass 2125 Hz and 2295 Hz and reject or sharply attenuate all frequencies beyond the limits of 2000 Hz and 2500 Hz. This filter response looks very similar to the receiver bandpass filter response in the previous article. In fact, they are quite alike.

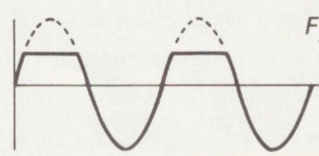


Fig. 13—Clipping effect of D2.

There are several types of bandpass filter circuits; however, they work on essentially the same principle. Consider fig. 8. Both L_1 — C_1 and L_2 — C_2 are designed to resonate on 2210 Hz (the center frequency of 2125 Hz and 2295 Hz). The idea is that desired frequencies within the bandpass (2000 Hz to 2500 Hz) will travel through the filter without being affected; but the unwanted signals, that is, signals whose frequencies lie outside the band-

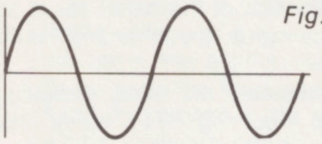


Fig. 14—Input signal waveform.

pass, will meet high series impedance through L_1-C_1 and a low parallel shunt impedance through L_2-C_2 (to ground) and thus be attenuated. In this way the door is closed somewhat to signals which might interfere with the desired ones.

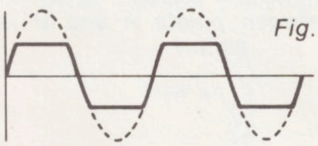


Fig. 15—Output signal waveform.

Just one more word about signal filtering. If your mental machine is working overtime you may have asked: What about attenuating signal frequencies *between* 2125 Hz and 2295 Hz? It can be done — with a device called a *notch filter*. The notch filter's response is such that all frequencies below 2295 Hz and above 2125 Hz are attenuated. See fig. 9.

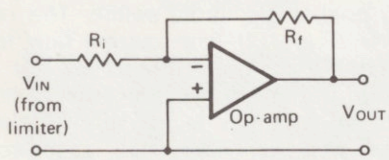


Fig. 16—Basic operational amplifier circuit.

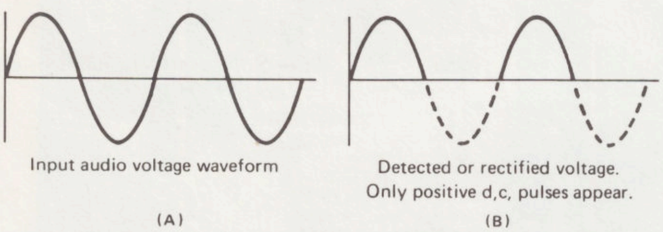


Fig. 17—Changing an a.c. waveform (voltage) to a d.c. waveform (voltage) through the process of detection.

The Limiter/Amplifier

If the incoming audio signal level from the receiver output is above a predetermined level the signal is *limited* (or *attenuated* or *clipped*); if the output signal of the receiver is too weak it is amplified. In this way constant and equal voltage levels for mark and space are maintained.

To make the function and operation of the limiter/amplifier more lucid, it would be wise to digress a bit and discuss the nature of f.m. signals.

RTTY transmission is a form of frequency modulation. This can be illustrated with the aid of fig. 10. Notice that the amplitude (height) of the signal wave remains constant. If, in fact, the amplitude varied the signal would be amplitude modulated, or a.m.

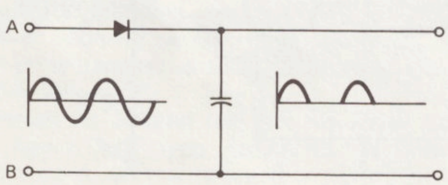


Fig. 18—Simple detector circuit.

The mark pulse contains more cycles of wave than the space pulse per unit time — 170 more. This means that in one second the mark tone will move up and down 2295 times and the space tone will move up and down 2125 times.

This f.m. signal behaves as any other f.m. signal, for example, as f.m. broadcast radio or 2 meter f.m. One of the advantages of FSK is that it *is* f.m. The (f.m.) receiver, i.e., the demodulator, will "capture" the strongest signal on the frequency and reject all others. Good f.m. is QRM-free. However, it can also be signal-free if the receiver captures noise which happens to be stronger than the desired signal. In that case, the signal is lost. F.m. (fsk RTTY) reception works *only* if the signal is stronger than the noise. The bandpass filter takes care of a greater part of the noise; if the input bandwidth is decreased, the signal-to-noise ratio is correspondingly improved. The limiter/amplifier takes care of the signal.

Figure 11 shows a simple diode limiter circuit. As the amplitude of the input signal increases, the negative peak of the output signal cannot rise beyond the d.c. bias voltage on D_1 and the signal is clipped below. See fig. 12. Similarly, as the amplitude of the input signal increases,

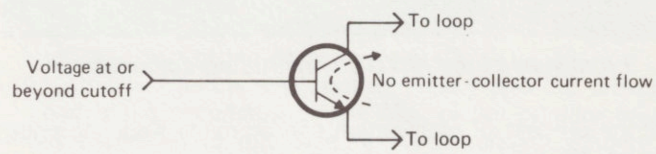


Fig. 19—A switching transistor as an open circuit.

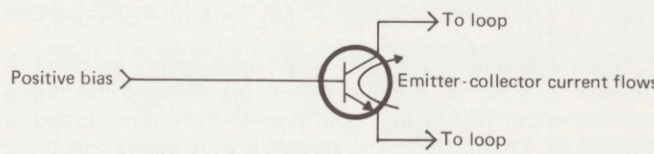


Fig. 20—A switching transistor as a closed circuit.

the positive peak of the output signal cannot exceed the d.c. bias voltage on D_2 and the signal is clipped above. See fig. 13.

The combined effect of D_1 and D_2 is to clip both the top and bottom peaks of the input signal. If fig. 14 is the input signal wave form, then fig. 15 is the clipped output signal waveform.

The result is that an incoming RTTY signal is clipped to a constant amplitude if it is at too high an amplitude level when it enters the limiter.

On the other hand, if the input signal is too weak, the signal is amplified to the predetermined level. This result can be achieved by any of several amplification techniques, the most popular now being use of the ubiquitous operational amplifier *(op-amp)*.

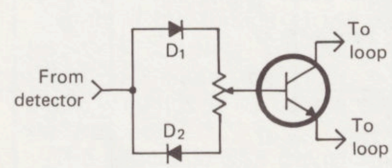


Fig. 21—Simplified keyer circuit.

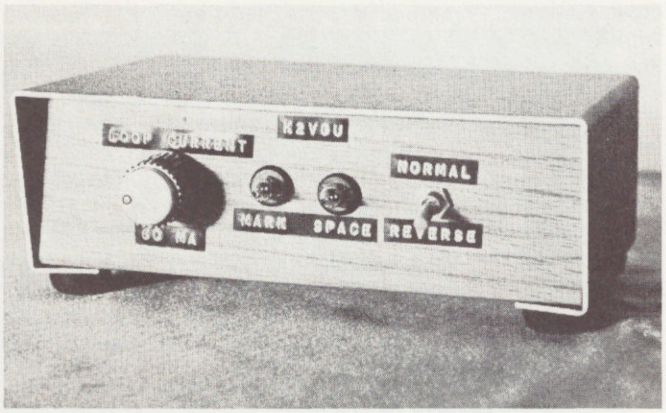
Figure 16 shows a basic op-amp circuit. R_1 is called the input resistance; R_f is called the feedback resistance. The output voltage can be kept at a constant level by assigning the values of R_1 and R_f according to the prescription

$$V_{out} = V_{in} \bullet \frac{R_f}{R_i}.$$

The Detector

The *detector* is the stage of the converter which changes the audio tones into d.c. pulses. The two RTTY audio tones are fed into the detector at frequencies of 2125 Hz and 2295 Hz. The input signal type is a.c.; the output signal type is d.c. See fig. 17.

The detector works on the same principle as any diode rectifier. In most detectors, use is made of the one-way conductivity property of solid-state diodes. A closer look



Front view of the K2VGU constructed demodulator.

at the process of rectification can be made with reference to fig. 18.

The input signal is a varying voltage, first going positive, then going negative; repeating the process again and again in a short time interval (for a mark tone, 2295 times in one second).

When the injected signal is positive-going at point A (relative to point B) conduction occurs through the diode and the upper half of the input waveform is reproduced at the output. When point A is negative with respect to point B, no conduction occurs, thereby clipping the lower half of the input waveform. The resultant voltage thus produced at the output is positive d.c.

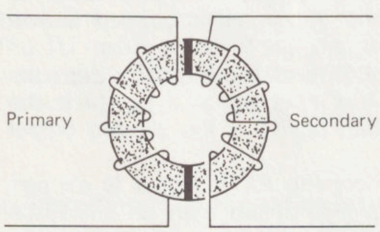


Fig. 23—Illustration of a toroid.

It might be noted that the function of the capacitor is to hold the peak positive voltage value (by charging) until the next positive pulse arrives.

Thus the detector stage completes the basic demodulator function of changing the incoming RTTY tones into d.c. pulses.

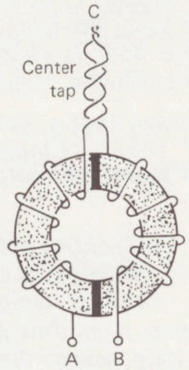


Fig. 24—Wiring a toroid. The inductance between points A and B is 88 mH.

The Keyer

The *keyer* stage of a TU is a switching device, alternately turning the loop supply current to the selector magnets on and off. As was pointed out in the previous article, the keyer acts as a single pole-single throw switch. The required switching conditions are (1) loop current flow for a mark (switch *on*) and (2) no loop current flow for a space (switch *off*). There are several ways of turning the loop current on and off, among them being use of a tube, use of a relay, and use of a transistor. This discussion will consider transistor switching.

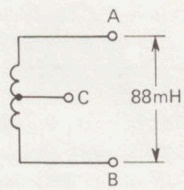


Fig. 25—Schematic diagram of an 88 mH toroid.

The base of a transistor acts as a valve of sorts to current flow from the emitter to the collector of a transistor (very much like the grid's relationship to the cathode and the plate of a vacuum tube). If the base is biased at or beyond cutoff, no current will flow from the emitter to the collector and the transistor acts effecively as an open circuit. See fig. 19.

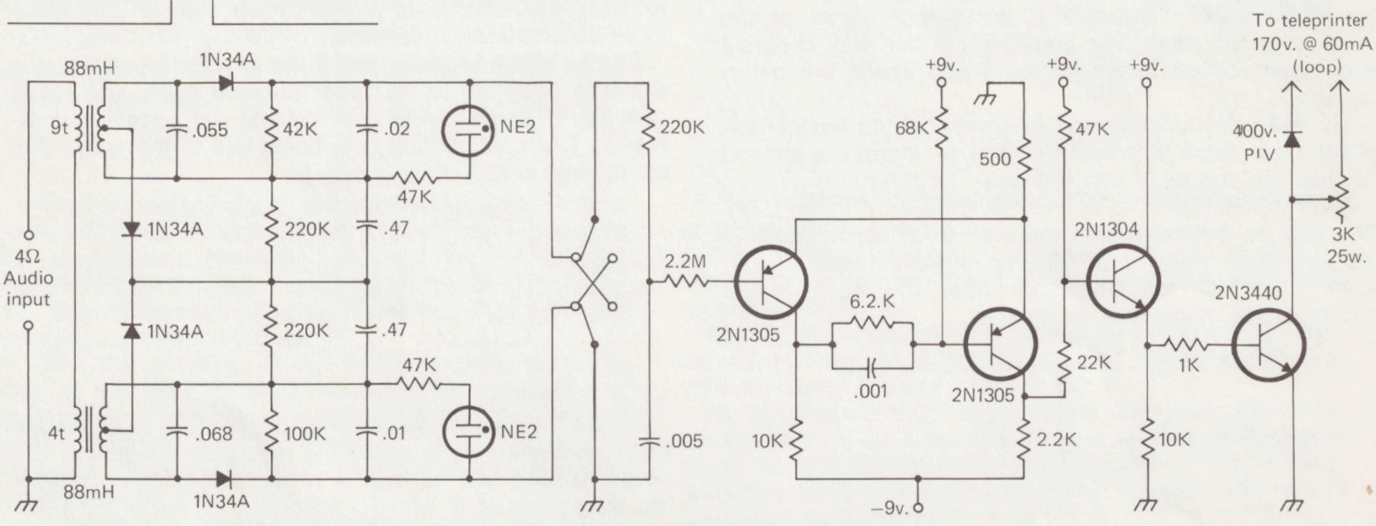


Fig. 22—Schematic diagram of the demodulator.

A transistor is chosen whose cutoff bias corresponds to the voltage of a space pulse. When a space pulse feeds the base, the emitter-collector circuit is open, no current flows and the loop circuit remains open. On the other hand, if the base is fed with a mark pulse (a positive bias), emitter-collector conduction occurs, current flows through the transistor and the loop circuit is closed. See fig. 20.

Mark and space pulses reach the keyer transistor through diodes. See fig. 21. On positive pulses current flows through D_1 only and keys the transistor so that the loop circuit is closed. On negative pulses current flows through D_2 imposing cutoff (or beyond-cutoff) bias of the base, thereby preventing a closed circuit between the

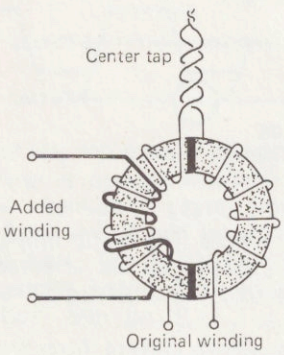
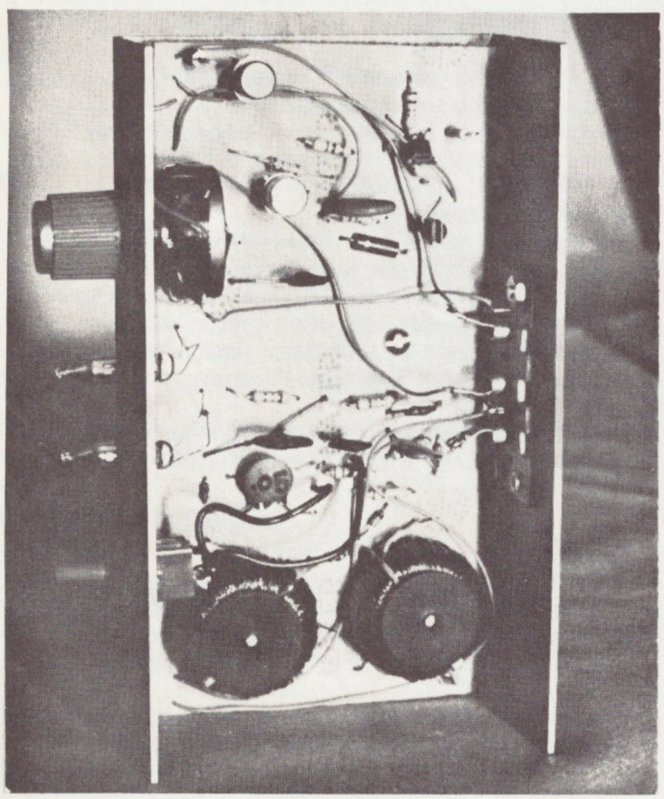


Fig. 26—Adding the coupling link to the toroid.



Interior view showing the two toroids and the point to point wiring that is done on perf board.

emitter and collector; thus opening the loop. Therefore, the selector magnets are activated or not by positive pulses or negative pulses, respectively.

The potentiometer is used to balance the positive and negative pulses.

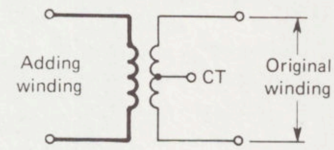
It should be pointed out that the keyer transistor must be a "heavy duty" type, having to key voltages upwards of 170 volts at 60 mA (more than 10 watts).

This completes the detailed functional description of the stages of a basic demodulator. The discussion is by no means comprehensive. In fact, in order to aid in the understanding of the various stages' operation, the circuitry was deliberately pared to the barest essentials. A few of the circuits as presented would not perform well in practical use. Their simplification was an instructional device, not a plan for construction.

Demodulator Construction

The demodulator described in this article (fig. 22) is an adaptation of one previously published.[1] Construction is quite simple and the components are easily obtained. The only parts of the demodulator which may require special attention are the toroids. The ones used in this project are surplus 88 mH toroids. They can be bought very cheaply (about 70 cents each) from various suppliers who advertise in the amateur radio magazines.

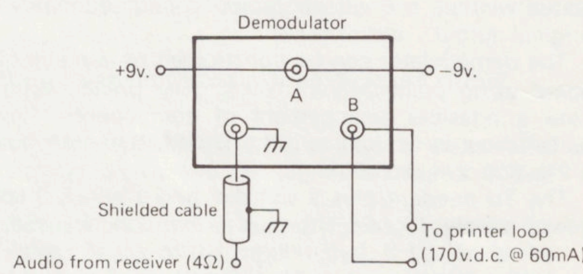
Fig. 27—Schematic diagram of the modified toroid.



A toroid is simply a transformer wound on a doughnut-shaped (toroidal) iron core. There are two windings, one on each half of the core. See fig. 23.

One half (either one) is the *primary* and the remaining half is the *secondary*. If one side of the primary winding is connected to one side of the secondary winding the inductance between the two remaining leads approximates 88 mH.

Refer to fig. 24. Here one side of the primary has been joined to one side of the secondary, forming a pigtail at point C. This pigtail is called the **center-tap** of the toroid. The *inductance*, then, between points A and B is 88 mH.



NOTE:
Plug A and plug B *must* be insulated from the chassis.

Fig. 29—Installation of the demodulator.

Figure 25 shows a schematic diagram of fig. 24.

The wire used to wind a toroid is laminated and thus insulated. Before making any solder connections to the toroid it will be necessary to scrape them clean of the laminate. This can be done with the edge of a small knife.

Each of the toroids in the demodulator will require an additional winding. You must supply them. One toroid needs four turns; the other, nine turns. The function of these windings is to couple the receiver audio output to the converter.

The additional wire (transformer wire or wire taken from another toroid can be used—but make sure the wire is laminated) must be wound in the same direction as the windings on the toroid. The finished modified toroids should look like fig. 26.

[1] *The Teleprinter Handbook* (An RSGB Publication), The Garden City Press, Ltd., Letchworth, Hertfordshire SG6 1JS, Great Britain, 1973, p. 5.11.

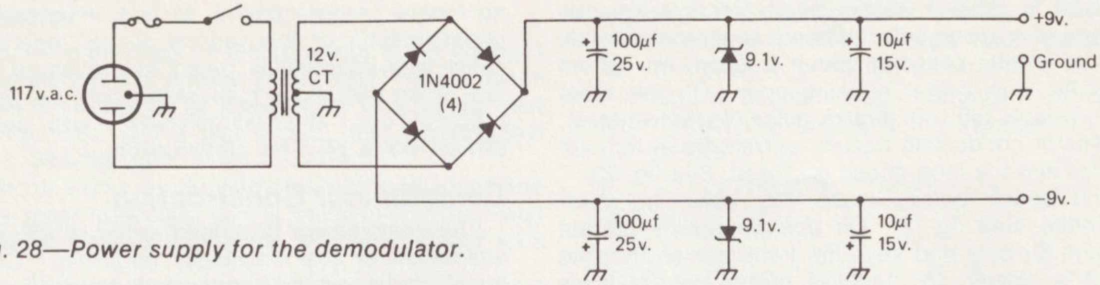
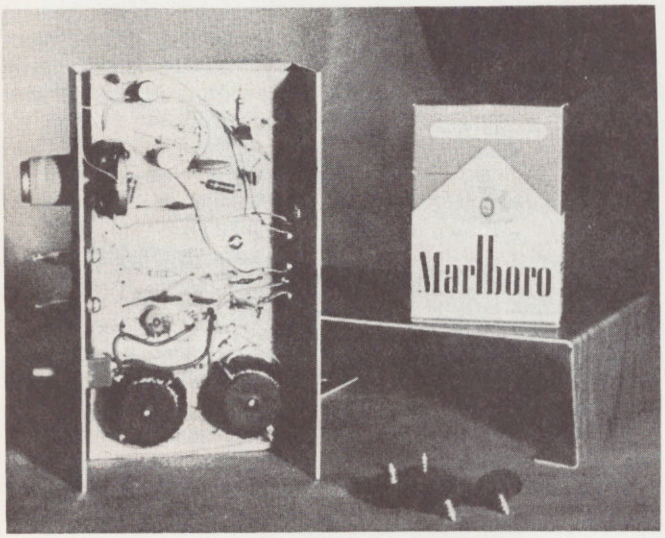


Fig. 28—Power supply for the demodulator.



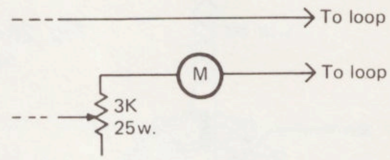
The demodulator is shown for a size comparison with a pack of cigarettes.

Schematically, the toroids are now represented by fig. 27. The final result is a transformer whose primary is the added winding and whose center-tapped secondary is the original toroid.

The demodulator can be constructed on a piece of perfboard using point-to-point wiring. The photographs illustrate a possible arrangement of components. However, parts layout is not critical. My demodulator was built into a 2¾ × 6 × 4 inch box.

The TU needs a plus 9 volt d.c. and a minus 9 volt d.c. power supply. Fig. 28 shows one that can be used; or, if available, power can be drawn from an existing piece of equipment.

Fig. 30—Adjusting the loop current. The meter is 0-100 mA.



Installation of the unit is quite simple. The audio output (4 ohms) of the receiver is fed into the TU via shielded cable. The "to printer" leads tie into the loop supply of of the teleprinter. See fig. 29.

The potentiometer is used to adjust current from the loop supply. To get an accurate current draw put a 0 to 100 ma ammeter in series with the loop supply. Refer to fig. 30.

Start the current adjustment at the center of excursion of the pot to avoid transistor burnout.

The converter is sensitive to 170 Hz shift only. Tune across a signal until both the mark and space neon lamps flicker with equal brilliance. The teleprinter should react. Tuning must be done *very slowly.*

The d.p.d.t. switch is a "normal-reverse" switch. It allows copy of either low tone for space and high tone for mark (normal) or low tone for mark and high tone for space (reverse). Most stations send "right-side up" (normal). Some stations, through design or oversight, send "upside-down" (reverse). If copy is garbled, try flipping the switch.

My thanks to Harlan Kramer, WA2HPS, for the fine photography.

Part IV

This installment of the series introduces the principles of teletypewriter operation along with a description of several machines. In addition, some readers' questions are answered.

The heart of the RTTY station is the teleprinter. There is quite a variety of these machines, in both kind and price, available to the radio amateur. However, before actually getting into a discussion of the operation and availability of mechanical gear it may be interesting to have a look at a short history of teleprinting communications.

In 1844 the invention of the first servicable telegraph system by Samuel F. B. Morse changed the complexion of long distance communications. For the first time instant contact was possible over significant distances. Yet, despite the general adulation of Morse's invention, there were some major drawbacks.

First, the mode of communications was aural - it had to be heard before it could be recorded.

Second, it required special training since, at the time, Morses's code of dits and dahs was the exclusive property of communications specialists.

Third, telegraphy required two operators, one at each of two points, to be present at the same time for sending and receiving messages.

And fourth, telegraphy was slow. It was (and still is) rare, indeed, to have the ability to send and receive the Morse code in excess of fifty words per minute.

The thrust of communications researchers, then, moved in the direction of developing a system whereby messages could be sent and received automatically, in final printed form, at speeds and with reliability not possible with hand-processed Morse code.

In 1848 R. E. House patented an invention destined to become the ancestor of modern teleprinting equipment. His

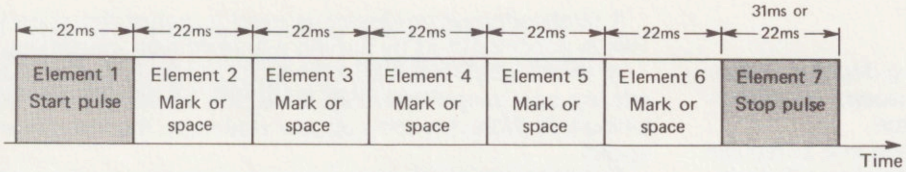


Fig. 1 – Five-level code with "start" and "stop" pulses added.

machine had a keyboard not unlike that of a piano and used compressed air which was conduited through a series of rubber tubes to actuate the printing mechanism. The final printed message appeared on a strip of tape.

A giant leap forward occurred in 1874 when a Frenchman, Emil Baudot, invented the five-level code which now bears his name. It could be used for both sending and receiving messages. The Baudot code was the precursor of today's Murray code.

The Teletype® Corporation came into existence in 1907. It was originally a joint venture of Joy Morton (of salt fame) and Charles Krum (or Krumm). The parent company was called Morkrum.

By 1908 a servicable system had been developed whereby landline messages could be sent and received over distances in excess of 150 miles. One of the remaining engineering problems, however, was finding a way to synchronize the sending machine's speed with the receiving machine's speed so they would run in step. Howard Krum (Charles' son) solved the problem with an ingenious solution.

The answer took the form of prefixing each five-level character group with a "start pulse" and appending each five-unit group with a "stop pulse." This method of machine phasing is called **start-stop synchronization.** To understand the younger Krum's idea it is necessary to review the five-level code.

Note that on Western Union machines the total character length (including prefixed and appended pulses) is 154 ms; (see fig. 2) Bell machines have character length totalling 163 ms. (See fig. 3) Nevertheless, the two types of machines are completely compatible.

By 1930, with the synchronization problem solved and with the introduction of the Model 15, teleprinting communications had reached maturity and international acceptance.

A typical page printer is made of the following major components: a keyboard, a motor unit and a typing unit (page printer).

Each of these components will be discussed in turn with emphasis on basic function and operation.

The Keyboard

There are several types of keyboards. Their design is a function of the use to which the teleprinter is put. In general, the board is arranged in three rows of keys (unlike an ordinary typewriter, which has four). The upper-most row is used to type numerals when the machine is in the **figures shift** position. The middle and lower rows are used to print punctuation marks and special characters when in the figures shift position. Letters, of course, are printed when the board is in the **letters shift** position.

The four major types of keyboards in use are the *Bell System business board,* the *Western Union board,* the *weather-type board,* and the *communications-type board.*

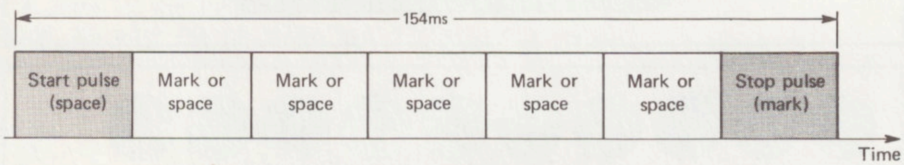


Fig. 2 – Typical Western Union character. Each element is 22 ms long. The total character length is 7 x 22 or 154 ms.

Each character (alphabetic, numeric and special) and each nonprinting function (linefeed, carriage return, space, blank, letters shift and figures shift) is represented by a combination of five *marks* and/or *spaces*. Each *mark* and each *space* is 22 milliseconds (ms) long for machines running at 60 words per minute (w.p.m.)

When no character is sent the teleprinter is in **markhold** (a steady mark is transmitted). The receiving teleprinter's motor is running but the keyboard is inactive. When a key is depressed on the sending machine, the sending mechanism is engaged (loop circuit opened) and a *space* is sent. This space signal moves the receiving teleprinter to space and activates its receiving mechanism. The distant machine is now ready to copy a character.

After the character is copied (i.e., after one rotation of the receiving mechanism) the distant teleprinter returns to mark-hold and awaits the next space signal (*start pulse*).

The **start pulse** is, by convention, as long as a single element of a character (22 ms for 60 w.p.m.). The stop pulse's length can vary. On Western Union machines it is 22 ms; on Bell machines it is 31 ms. The stop pulse can, in fact, be any length. Fig. 1 shows a typical five-level character with start and stop pulses added.

By using start and stop pulses two machines can be synchronized with respect to speed of operation.

For the sake of comparison two boards are illustrated. These are the standard communications-type board (most often used by amateurs) and the weather keyboard. See figs. 4 and 5.

A good starting point for understanding the operation of a keyboard is its underside. See fig. 6.

Note that five crossbars lie under the keylevers. The crossbars are perpendicular to the keylevers and can move laterally.

The crossbars are notched in such a way that when a key is depressed the key lever moves the crossbars sideways. See fig. 7 for an illustration of a typical crossbar.

Some of the crossbar notches are vertical so that when a keylever moves into them there is no movement of the bars. Therefore, when and how far a particular crossbar is moved by a keylever is determined by the geometry of the crossbar itself.

The crossbar's final position, relative to the keylever which is depressed, translates to either a mark or a space element of the Murray encodement for a particular character. Movement of the bar to the left encodes a mark and movement of the bar to the right encodes a space.

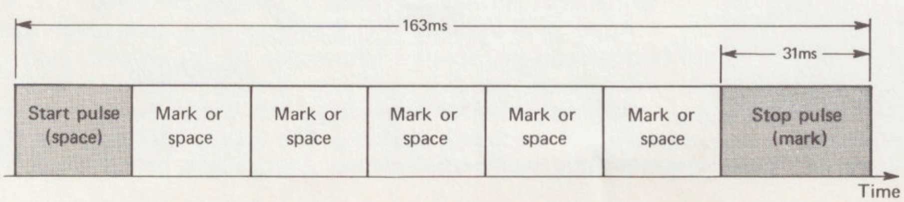


Fig. 3 – Typical Bell System character. Each element is 22 ms long, with the exception of the "stop" pulse, which is 31 ms long. The total character length is 163 ms. Note that Western Union and Bell System teletypewriters are completely compatable.

The Motor Unit

There are three types of motors in varying degrees of use. They are the *governed motor*, the *series-wound (or series-field) motor* and the *a.c. synchronous motor.*

Regardless of which one of these is found in a particular machine the motor is used to mechanically power the teleprinter. The motor is geared from a shaft to each of the typing units, the keyboard and the keyboard transmitter shaft. The governed motor can be identified with associated passive components. If the motor has in its circuit a complement of resistors and capacitors it is almost certain that it is governed. Of course, the obvious drawback of such a motor lies in the fallability of the passive components. When any one of them fails, so does the motor speed accuracy.

Another problem associated with the governed motor is that it must be "tuned up" periodically. The speed of the motor is subject to variation (possibly caused by changes in assocatiated component values).

A stroboscope-type device is used to adjust the speed. This is accomplished by turning a screwdriver adjustment.

While the screw is turned a governing target is watched. A rotating spot target is viewed through a vibrating (120 Hz) tuning fork. When the spots appear stationary, the motor is on speed.

The series-wound motor's speed is controlled by the load across it. When the load is light the motor will run at high speed; if the load is increased, the speed is decreased. Obviously, the speed of the motor (and its accuracy) is a function of the load placed in shunt with it. If the load changes, the speed changes.

The synchronous-type motor is the most reliable. Its speed is a function of the line voltage frequency. The speed of the motor is generally either 1800 r.p.m. or 3600 r.p.m. In addition, since there are no brushes in the motor casing, there are no electrical connections to any moving parts.

The synchronous-type motor is, by far, the most reliable in terms of speed consistency and minimum required maintenance.

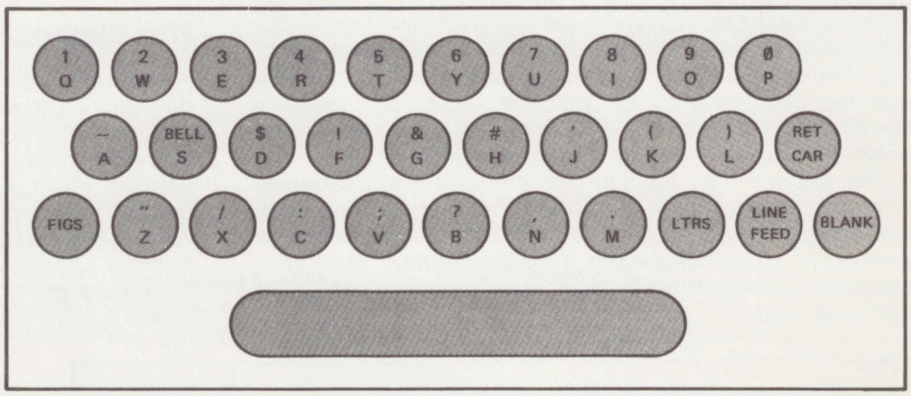


Fig. 4 – The standard communications keyboard.

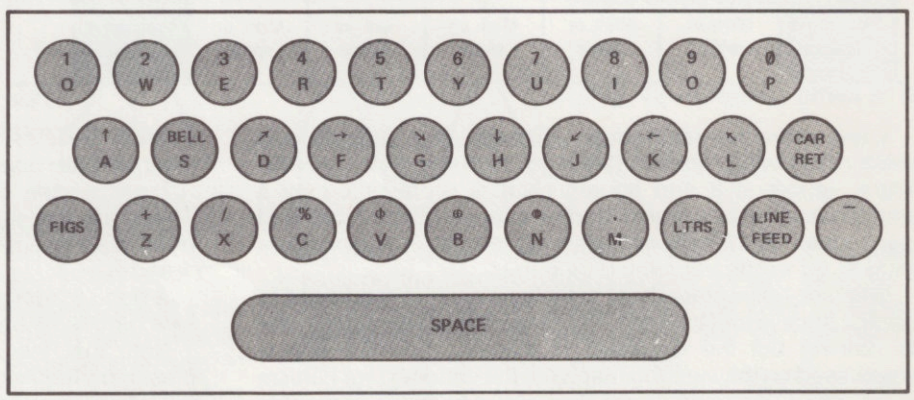


Fig. 5 – The "weather-type" keyboard.

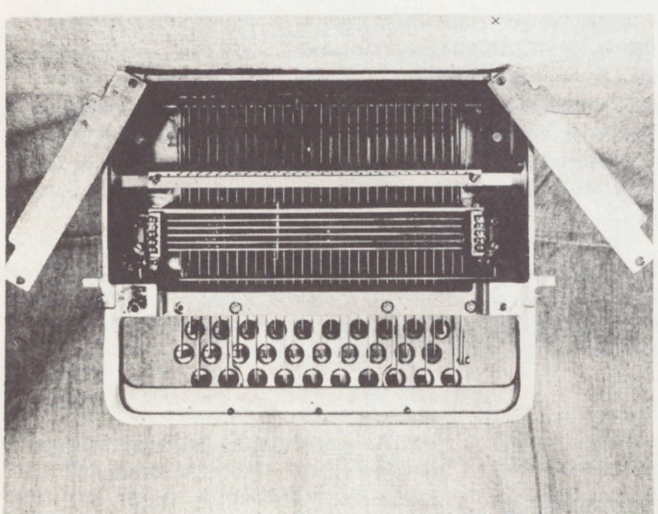


Fig. 6 – The underside of a (typical) keyboard. The five crossbars are seen perpendicular to the key levers.

The Typing Unit

The crux of the page printer (typing unit) is the **selecting mechanism.** See fig. 8.

There are five code bars (*not* crossbars, as in the keyboard) in the mechanism. Each bar is associated with one mark or one space pulse in a particular character's Murray encodement.

The receiving mechanism of a teleprinter determines the positions of the code bars. The combination of marks and spaces lines up the code bars under the corresponding pull bar whose movement activates the type bar to finally have the hammers hit the page.

There are many variations on this theme. However, the basic receiving mechanism operation and the basic character hammer activation remains essentially the same.

Appending this article is a bibliography from which the reader can get specific information for a particular model machine and see that machines operation in greater detail.

As indicated at the beginning of this article, there is a large variety of machines available. The quality and the price of machines run the whole gamut. It is possible, however, to get

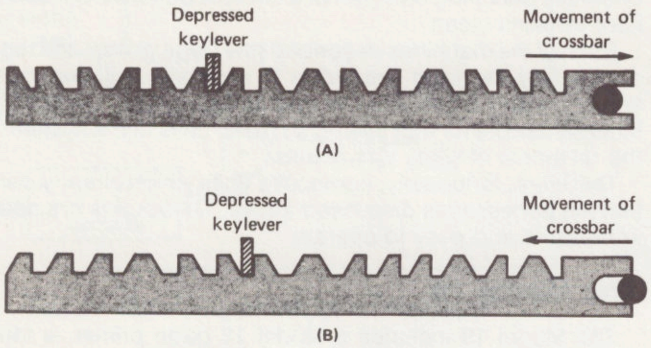


Fig. 7 – Illustration of how a ley lever moves a crossbar. In (a) the crossbar is moved to the right, encoding a space. In (b) the crossbar is moved to the left, encoding a mark.

a machine in working condition for a good price if you are patient enough and look hard enough. The best sources are hamfests, buy and sell ads and, of course, amateurs who are already into RTTY. If you are truely interested in persuing the mode at this point, it might be a good idea to find a "big brother."

There are three types of machines in greatest use: the Teletype® Corp. Models 15, 26 and 28. Each is a page printer.

The Model 15

This machine is available with and without a keyboard. If possible, get it with the keyboard, since without it, you cannot transmit. The 15 is capable of running at speeds of 60, 75, and 100 words per minute. Make sure that yours runs at 60 w.p.m., or if it doesn't, that you can get the appropriate gears.

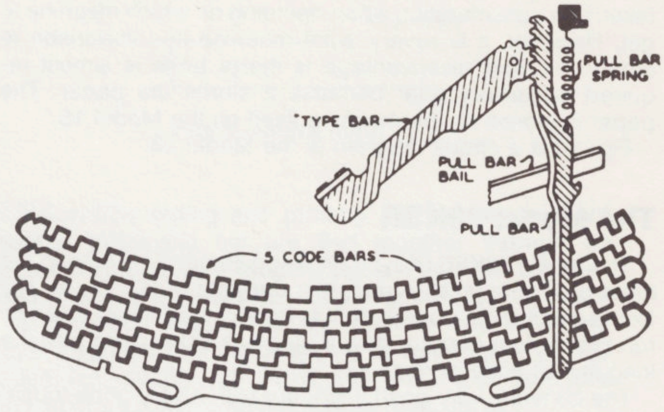


Fig. 8 – The selecting mechanism.

The gears are not expensive.

Some 15's come with a table on which it is meant to rest (the table model number is XRT-97). Get one if you can—it makes life easier and it contains the power supplies needed to run the machine.

The Model 15 was designed for continuous-duty use and is very reliable. However, it is large and rather noisy.

Fig. 9 is a wiring diagram of the Model 15.

The Model 26

The 26 is smaller than and operates much quieter than the 15. The model number of the matching metal table is 26A.

The Model 26 can come with either a d.c. governed motor or an a.c. synchronous motor. For reasons cited earlier, try to get one with the synchronous motor.

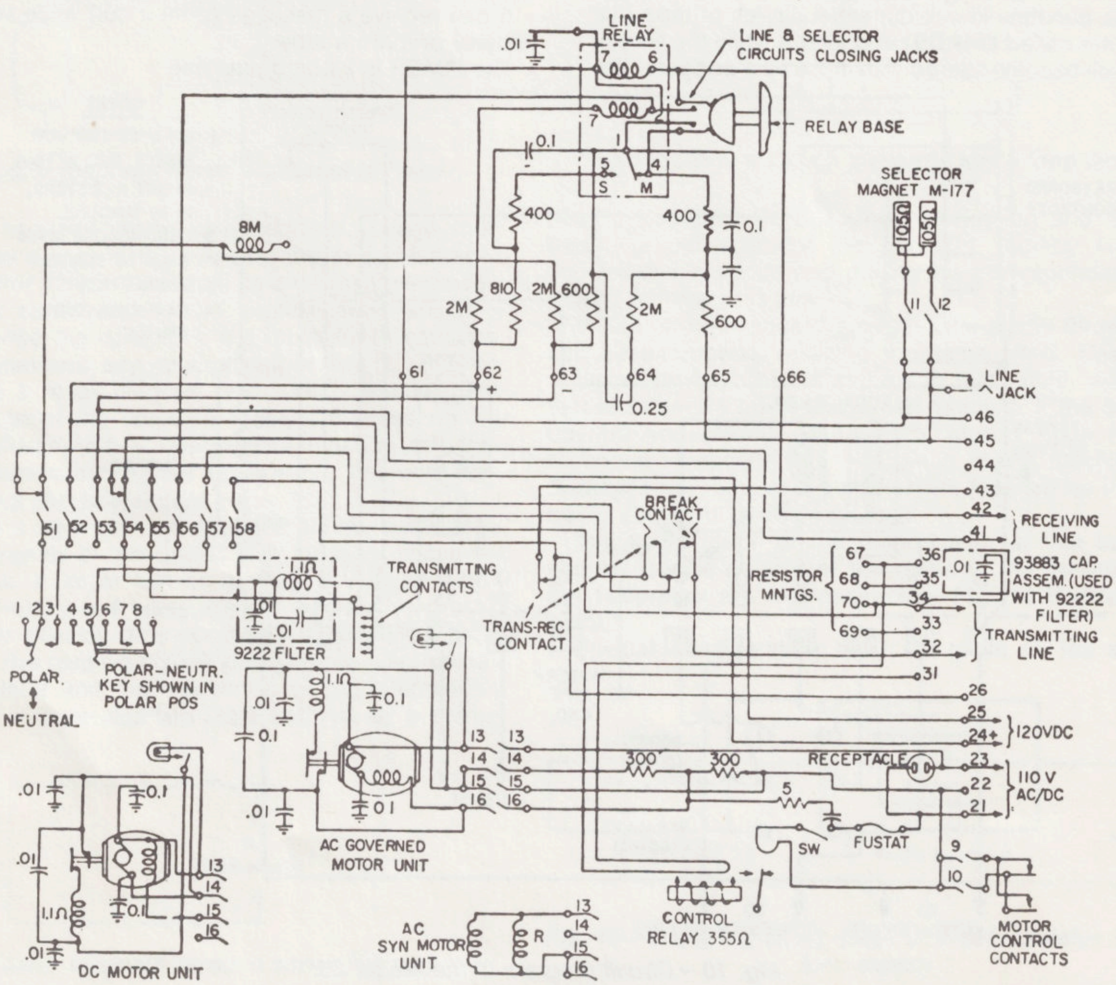


Fig. 9 – Wiring diagram of the Model 15.

The Model 26 is a light duty machine (originally used not more than three or four hours per day) and this fact should be taken into consideration when deciding on which machine to get. However, it is a very quiet machine in comparison to others. Another disadvantage is that a table is almost required accessory gear because it stores the paper. The paper is stored on the machine itself on the Model 15.

Fig. 10 is a circuit diagram of the Model 26.

The Model 28KSR

The Model 28KSR (**K**eyboard **S**end-**R**eceive) is among the most desirable units in use. It is capable of 60, 75, or 100 words per minute operation. It is quiet, streamlined and can run twenty-four hours a day. It also has associated with it a long line of accessories.

The 28 has a very good keyboard with a very good touch.

Unfortunately, it is expensive. Four hundred dollars is not an unusual price. Get one if you can.

The Model 28 sometimes comes with a governed motor. If yours does, check its speed accuracy.

The machines listed above are called page printers. As the name implies all they can do is print a page from an incoming signal and send a signal out via the keyboard.

There are, however, much more exotic pieces of equipment available.

The Model 14 is a tape reader (a TD, tee-dee, a **T**ransmitting **D**istributor). This machine can activate the sending mechanism from a piece of punched tape.

The tape itself is 11/16 of an inch (17.5 mm) wide. A tape punch (another one of those delicious accessories) punches holes in the tape. The holes (or lack of holes) correspond to the marks and spaces of the Murray code. The TD is designed to read the encodement and impulse the sending mechanism at the right time with the right voltages.

Some tape punches knock out small circles of tape (the little pieces are called **CHADS**) and after a while the floor of your shack will become littered with these little buggers. The best type of tape punch to get, then, is a *chadless* one. With chadless punching only part of a circle is punched out so the floor remains clean.

Each of the machines described (the page printer, the tape punch and the tape reader) is a separate unit that must somehow find a place at the operating position. One of the inherent problems with having so many units in the system is the rat's nest of wires that results.

There are, fortunately, composite units which already contain the accessories discussed above. These units are neat, impressive and easy to operate.

The Model 19

The Model 19 includes a Model 15 page printer, a tape perforator (alas, not chadless), a TD to play the tape, a character counter (so you know when a line ends if your punching tape) and a built-in power supply.

All the gear sits nicely on a metal desk which comes with the unit.

The Model 19 is very desirable.

The Model 28ASR

This model (fig. 11) is the most desirable with respect to performance judged against price. It can be set up in a myriad of ways by virtue of the accessories available for it. For example, you can have automatic non-overline control (to guarantee that one line does not print on top of the next one), automatic carriage return (which prevents pile-ups at the end of a line). It can make a bell ring when someone sends your call letters (but not somebody else's) and a host of other things.

It may come with an auto-stop tape reader, i.e., when the last character on a tape is read, the reader shuts itself off automatically.

It can receive a message (print it out) while you simultaneously prepare a tape.

The 28ASR is a *primo* machine.

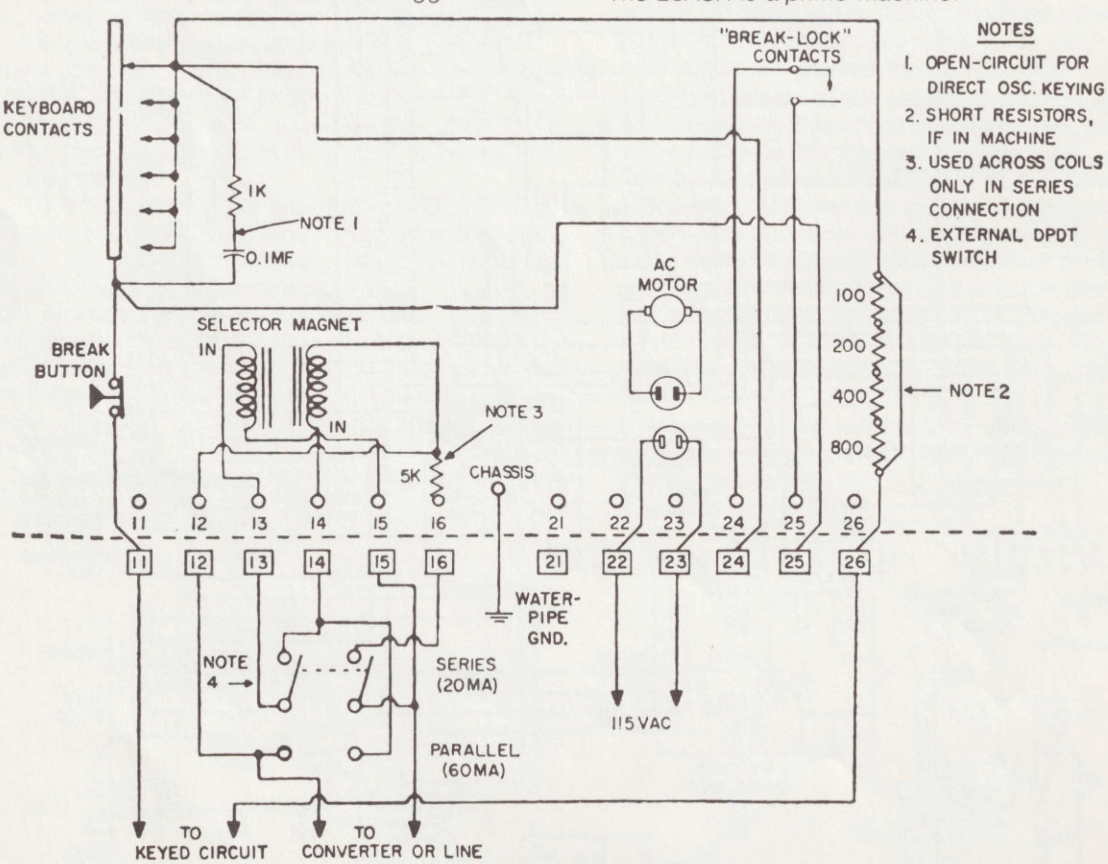


Fig. 10 – Circuit diagram of the Model 26.

A much more detailed description of all machines' operation and maintenance is handsomely presented in some of the books in the appended bibliography. A ten or fifteen dollar investment in some of these volumes at this time will pay invaluable dividends in the future.

I would like to answer some of the questions I have received as a result of this series. It is almost certain that some of you are asking the same questions.

Q: I have an opportunity to buy a Model 19, complete with reperf and TD, for $200. Do you think that this is a reasonable price for the machine? It was completely overhauled and the owner is willing to throw in an extra number of parts.

A: It is very difficult to give advice on the purchase of (somebody else's) equipment, particulary through the mail. Used mechanical RTTY gear (such as the Model 19) and associated pieces can be found of every state of repair and disrepair, in price ranges that boggle the mind. As with the purchase of any piece of gear I suggest that you shop around a bit (possibly through the ads in ham journals) and talk up your idea over the air. In that way you can satisfy yourself as to whether a particular piece of equipment is worth the investment.

You also might get acquainted with a local amateur who is interested in RTTY and get some first-hand advice from him (or her).

Q: Is the "X"-brand receiver good for RTTY?

A: The reception of RTTY signals is a rather touchy process. It requires a very stable receiver which has rather special bandpass filter characteristics. In addition, it must have special b.f.o. injection frequency properties. The input bandpass filter must be quite narrow (in the order of 400-500 Hz for narrow, 170 Hz; reception and about 1000 Hz for wide, 850 Hz, reception). Furthermore, the center of the filter bandpass must be at the center frequency of the two RTTY tones. I suggest you look at the specifications of your receiver to see if it meets these requirements.

Q: Mechanical RTTY is too noisy for me. What about using video RTTY?

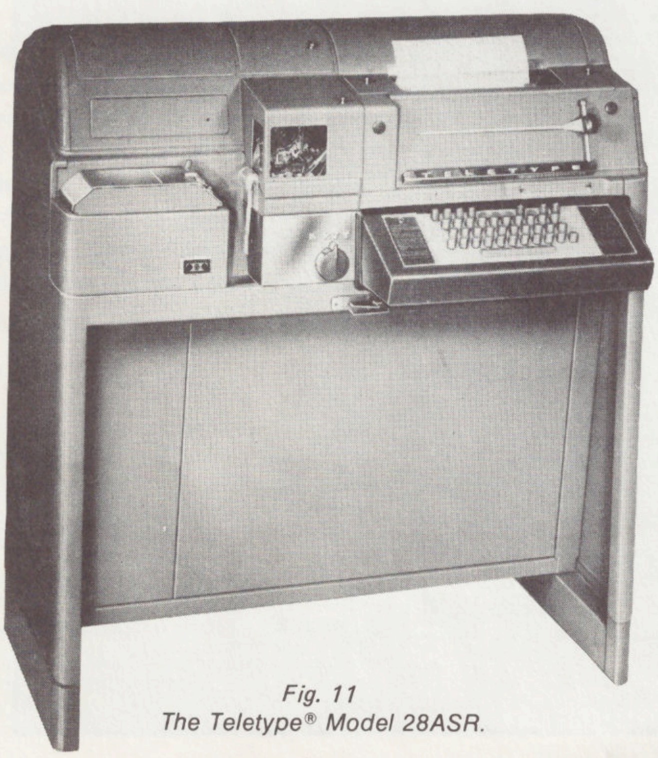


Fig. 11
The Teletype® Model 28ASR.

A: I am more than familiar with the noise generated by old mechanical teleprinters. Silent video RTTY is, indeed, the answer. But, it is expensive (a cheap set-up can cost in the order of $800) and it requires an experienced hand in putting it together and in maintaining it. Of course, they can be built for much less via home-brewing, but that would be a project to be undertaken by only the most knowledgable amateurs.

Q: How can I get a list of RTTY frequencies used by the various news and wire press services?

A: There is a very good booklet in print which lists not only commercial RTTY frequencies but also the language in which the copy is sent, the GMT of transmission, the speed and shift of transmission, the call letters of the station and the station's location. In addition, the book lists vital information for copying literally thousands of other stations on c.w., voice, fax, etc. The name of the booklet is *Confidential Frequency List*. The author is Robert B. Grove. It is published by Gilfer Associates, Inc., 52 Park Avenue, Park Ridge, NJ 07656. It costs $5.45.

Q: Do commercial stations use FSK or AFSK transmissions?

A: Commercial stations use both FSK and AFSK. However, on the receiving end it makes no difference which method is used. The receiver is electronically ignorant of any distinction.

Q: Must I have different demodulators to receive FSK and AFSK?

A: FSK and AFSK sound the same to all demodulators, i.e., one demodulator will be effective at receiving both. The distinction between the two shift methods is made at the transmitter. As long as the receiver is tuned to issue the proper mark and space tones, the demodulator couldn't care less if the signal was sent via FSK or AFSK.

If you have any questions whose answer evades you, let me know. If I don't know the answer, I'll try my best to find it for you. SASE will be appreciated.

The next installment will consider the theory and practice of generating frequency shift signals. It will include a simple construction project for a frequency shift keyer.

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In addition, there have been countless articles in the amateur radio journals throughout the years.

This part of the series will get you on the air. In addition to instructions for building a frequency shift keyer, on-the-air procedure is discussed.

Part V

The greatest concern in receiving RTTY is that of isolating and processing two audio tones which are separated by a given number of hertz. The major objective of transmitting RTTY is generating those tones.

The signal requirements are quite strict. First, the signal must consist of two radio frequencies separated by (let us agree) 170 Hz. Second, the accuracy of these tones must adhere to close tolerances — for if not, the converter on the receiving end will not respond to them. Third, the change from one frequency to the other must be effected instantaneously. And fourth, the stability of the transmitted radio frequencies must lie within proscribed limits.

In short, the transmission of a RTTY signal must lie hand-in-glove with its reception.

The terminal unit is designed to respond to two tones with a given frequency separation. The **frequency shift keyer** is designed to cause that separation.

This article will discuss the theory of frequency shift keying (f.s.k.) and will describe the construction of a frequency shift keyer using one of the two methods.

Frequency Shift Keying

The basic technique used for shifting the frequency of a transmitted signal is found through analysis of the relationship between the resonant frequency, f_r, of a tuned circuit and the values of the components in that circuit.

Consider fig. 1, which is a diagram of a parallel tuned circuit. The resonant frequency of the circuit is a function of the values of the capacitor, C, measured in farads and the inductor, L, measured in henries. The resonant frequency is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}},$$

where f_r is measured in hertz. See inset 1 for a derivation of the formula; see inset 2 for an example of using the formula.

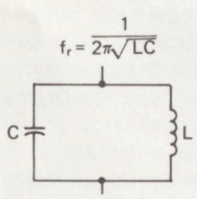


Fig. 1 – A parallel-tuned resonance circuit.

By changing either the value of L or the value of C in the tuned circuit of fig. 1 a corresponding change in its resonant frequency can be realized. For example, if the resonant frequency of the circuit in inset 2 were changed from 14.085000 MHz to 14.085170 MHz the seed of 170 Hz shift RTTY would be sown.

The simplest and, hence, most common method is to introduce a reactive change by varying the capacitance in the circuit.

Referring to fig. 2, note that a capacitor, C_p, has been placed in parallel with the tuned circuit. Upon doing this, the capacitance in the circuit increases (capacitances in parallel *add)* and the resonant frequency of the tank is thus lowered.

The capacitor can be switched, albeit manually, in and out of the circuit, as shown in fig. 3. When the capacitor is switched in f_r is lowered; when it is switched out f_r returns to its original value.

Frequency Shift Keyer Circuits

The foregoing discussion puts the reader in the position of being able to consider frequency shift circuits which are practical and in actual use. The simplest of these appears in fig. 4. A radio frequency choke (RFC), a trimmer capacitor (C_1) and a diode (D_1) are the only necessary components.

D_1 is normally reverse biased by the mark (positive) potential from the keyboard (+V is loop supply voltage). Under this condition there is no conduction through the diode and capacitor C_1 is switched out of the circuit. On transmission of a space pulse (–V), D_1 becomes forward biased and C_1 is introduced into the tank circuit C_2-L. This increases the capacitance and, thus, lowers the frequency of transmission.

C_1 is switched into the circuit in *parall* ' with the tank when D_1 conducts. A special note is made of this fact for, if not for the existance of a current return confusion in the analysis of the circuit might result. The capacitances of C_1 and C_2 *add.* This condition makes it relatively simple to find an appropriate value for the trimmer.

Note further that when a *space* is transmitted in the circuit of fig. 4 the diode is switched on and C_1 is switched in. The fact that the capacitor is switched in *lowers* the resonant frequency. When the diode does not conduct, the diode is switched off, the trimmer is not in the circuit and the resonant frequency is *raised.* These facts are in agreement with the

DERIVATION OF THE RESONANCE FORMULA

Capacitive reactance (measured in ohms) is given by

$$X_C = \frac{1}{2\pi fC}, \qquad (1)$$

where f is the frequency in hertz and C is the capacitance in farads.

Inductive reactance (measured in ohms) is given by

$$X_L = 2\pi fL, \qquad (2)$$

where f is the frequency in hertz and L is the inductance in henries.

A state of **resonance** exists when the capacitive reactance is equal to the inductive reactance, i.e., when $X_C = X_L$.

Thus, resonance appears when

$$\frac{1}{2\pi fC} = 2\pi fL \qquad (3)$$

Multiplying both sides of equation (3) by $2\pi fC$ gives

$$\pi^2 f^2 LC = 1 \qquad (4)$$

from which

$$f^2 = f_r^2 = \frac{1}{4\pi^2 LC} \qquad (5)$$

Thus,

$$f = f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (6)$$

Inset 1

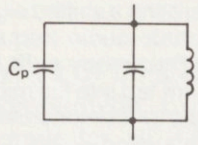


Fig. 2 – Changing the resonant frequency of a parallel-tuned circuit by placing a capacitor in parallel with it. The two capacitances add, thus lowering the resonant frequency.

convention among amateur RTTY-ers of low tone for space and high tone for mark. (Incidentally, there is a cute little mnemonic device for remembering the relationship between mark, space, low tone and high tone. It goes like this: LS/MFT — **L**ow **S**pace **M**eans **F**ine **T**eleprinting)

Keying the Keyer

The discussion now turns to the question of keying the keyer at the right time and in the right sequence for Murray encodement.

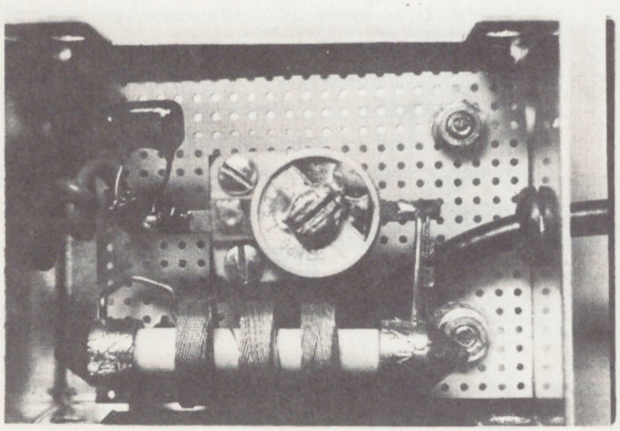
The switch used in a RTTY system for changing the frequency is the keyboard of the teleprinter. Refer to fig. 5. When a particular "arrow" (i.e., a keyboard contact) touches the upper line, the capacitor will be switched into the tuned circuit.

On the other hand, if an arrow is not touching the upper line the capacitance is switched out.

Therefore, if the arrows, moving in turn, from, say, left to right, make contact at the right time in accord with the Murray encodement of a particular character, that character will now be transmuted into its "high tone/low tone" representative. Since the teleprinter keyboard is designed to make and break contact within and during a prescribed amount of time (22 ms for 60 w.p.m. and instantaneous make and break) the mechanism of the teleprinter will take care of the switching requirements. This is basically how RTTY is transmitted. See fig. 6 for a diagram of how the letter "F" (M/S/M/M/S) is transmitted.

Moving sequentially from the encodement of element 1 (mark) to the encodement of element 5 (space), capacitor C_1 can be visualized as being switched in and out in accordance with the appearance of the marks and spaces for the letter "F." To make the diagram complete the timing sequency has been included, *viz.*, each pulse has a duration of 22 ms and the change from pulse to pulse (element to element) is instantaneous. The actual switching, of course, takes place inside the keyboard mechanism.

Note that throughout all of this the transmitter is sending a constant carrier. That is, the transmitter is operating under a continuous (100%) duty cycle. In that regard, it is *imperative* to note that, when transmitting RTTY, *the transmitter is always on*. If the transmitter is used in this way it is very easy to cause harm to the final tube(s). To be on the safe side **never run your transmitter so that the input power exceeds twice the plate dissipation of its final tubes(s).** The dissipation rating can be found in the specifications for your particular tube.



A closeup view of the finished 170 Hz shift keyer.

Construction of a Frequency Shift Keyer

A slight variation of the f.s.k.-er in fig. 4, and the circuit that will be used in the construction project, appears in fig. 7. This circuit is called a **saturated-diode** frequency shift keyer. It works on the same principle described earlier.

A pictorial representation of the finished product appears in fig. 8. Use the figure as a guide to construction.

The shift keyer is designed for use with 170 Hz shift only. If you are interested in using both 170 Hz and 850 Hz shifts, simply tack on another keyer as shown in fig. 9.

The 500 ohm potentiometer is used to adjust the shift for c.w. identification. The shift for c.w. identification is usually set for about 100 Hz.

The output of the frequency shift keyer can be connected to the oscillator of the transmitter in one of the following ways:

(1) To the cathode of the oscillator tube. This method is very common. The output lead is wrapped around the cathode pin of the tube and the tube is inserted in its socket.

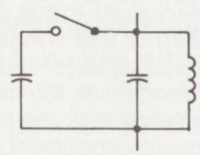
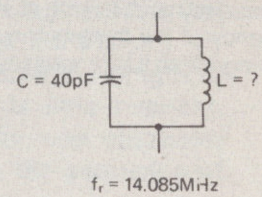


Fig. 3 – Switching a capacitor in and out of a tank circuit.

USING THE RESONANCE FORMULA

Problem: Assume an operating frequency of 14.085 MHz (this is in the "RTTY portion" of the twenty meter band). Given a capacitance of 40 pF (40×10^{-12} F), find the inductance necessary for the circuit to resonate at the operating frequency.



Solution: $f_r = 14.085 \times 10^6$ Hz
$C = 40 \times 10^{-12}$
$L = ?$

From

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

it follows that

$$L = \frac{1}{4\pi^2 f_r^2 C}.$$

Substituting the given values of f_r and C, we get

$$L = \frac{1}{4(3.14)^2(14.085 \times 10^6)^2(40 \times 10^{-12})};$$

whence,

$$L = 0.0000031 \text{ H}$$

or

$$L = 3.1\ \mu\text{H}.$$

Inset 2

(2) To the control grid of the oscillator tube. The method of connection is the same as above.
(3) To the base of the oscillator transistor. Here, the output wire must be soldered directly to the transistor.
(4) Directly to the tank of the oscillator.

There are other methods. These can be found by referring to the bibliography of Part IV in this series.

The keyer should be housed in a metal mini-box for maximum sheilding against r.f. It should then be mounted as close to the oscillator (or tank) as possible. The wire going from the keyer to the keyboard should be sheilded cable. The idea is to make the keyer as r.f. immune as possible.

Of course, the keyer will have to be adjusted so that it shifts the transmitter's frequency 170 Hz. If you have a frequency counter, you are in luck. Simply key the transmitter with the keyer in and out of the circuit so that the space frequency is 170 Hz lower than the mark frequency.

If you do not have a counter, you may have to resort to subterfuge in the following manner. Use a harmonica!

An octave above E above middle C has a frequency of 659.2 Hz; an octave above G# above middle C has a frequency of 830.5. It is significant that the frequency difference between these two notes is 171.3 Hz — close enough for the purpose of setting the shift.

Zero-beat the space signal on your receiver with the E; then generate a mark and zero-beat with the G# by adjusting the trimmer.

Sometimes it is impossible to get the proper shift regardless of the position of the trimmer adjustment. In that case you might need more or less capacitance than that of the trimmer. If you look closely at the photographs of my keyer you will see that there is a 10 pF capacitor in series with the trimmer. I needed less capacitance so the solution took the form of a series capacitor. You may also have to experiment a bit.

Audio Frequency Shift Keying (A.F.S.K.)

Frequency shift keying (f.s.k.) effects a change in the r.f. frequency of the transmitter. The signal is sent over the air, following which it is processed by the distant receiver into two audio tones. These audio tones are then fed into the converter. With f.s.k. what ultimately becomes two audio tones originates in the oscillator of the transmitter.

There is another method of generating a shifted signal. With this method two tones of appropriate audio frequency are generated by a device (an **audio frequency shift keyer,** or a.f.s. keyer) whereupon the tones are fed into the microphone jack of the transmitter. The two audio tones modulate a steady carrier in exactly the same way one's voice would. The carrier and one sideband (usually the upper) are supressed at the transmitting end, to be later reinserted at the receiver. In this way the receiver of the signal treats a.f.s.k.'ed signal as an s.s.b. signal. The properly tuned audio tones are then introduced into the demodulator.

Note that, regardless of the shift method, f.s.k. or a.f.s.k., the converter is electronically ignorant of any difference. All the TU responds to are two audio tones. It cares not of their roots.

In order for a.f.s.k. to be legal on the h.f. amateur bands the carrier and upper sideband must be supressed to a very great degree — in the order of 45 dB down. Many contemporary rigs meet this standard. Many older rigs do not. Watch that supression or the F.C.C. will get you!

On-the-Air Procedure

If you have been following this series faithfully you should now have in your possession a complete RTTY station.

The next step is getting on the air.

Although there are many similarities between operating c.w. or 'phone and RTTY, there are several differences in procedure and regulations that must be borne in mind.

First, not only must you identify every ten minutes, but you must identify *every time* you turn your rig on and off, *even if the transmission lasted but one-half minute*. Furthermore, identification must be made either by narrow shift "c.w." or by real c.w. Identification *via* the keyboard is the usual procedure during a QSO but the F.C.C. requires c.w. identification. Strangely, they do not require printed identification.

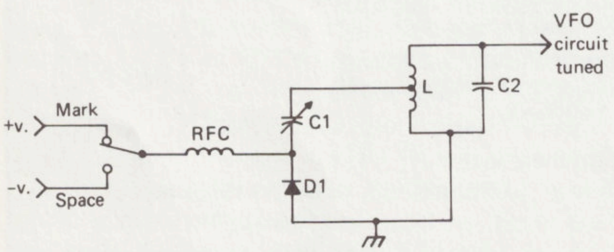


Fig. 4 – A simple frequency shift keyer.

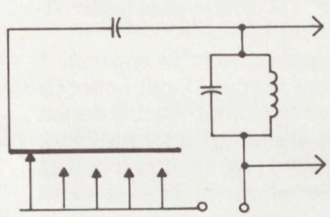


Fig. 5 – Using the keyboard of a teleprinter to switch a capacitor in and out of a tuned circuit.

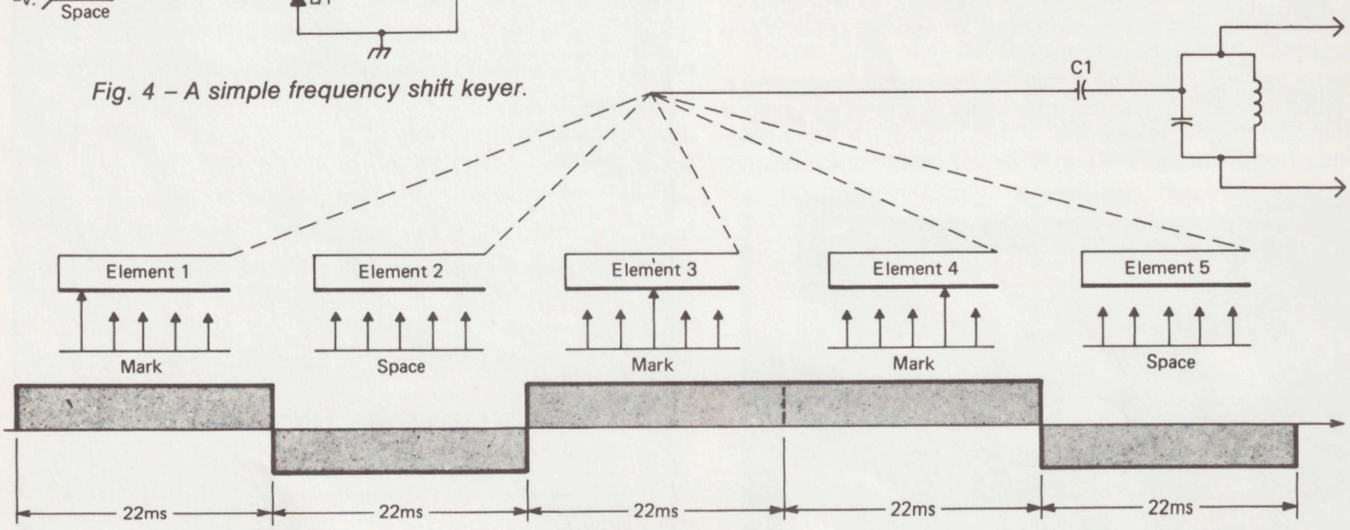


Fig. 6 – Illustration of how the letter "F" is transmitted by use of a keyboard and a frequency shift keyer. The marks and spaces are encoded as a function of whether the keyboard contacts are open or closed, respectively. Each keyboard contact is open or closed for 22 ms and the change from open to closed is instantaneous.

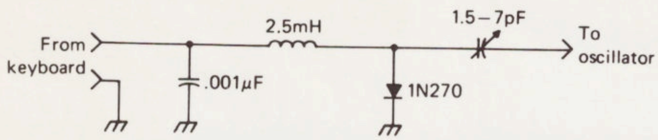


Fig. 7 – A practical saturated diode keyer. This is the schematic diagram for the construction project.

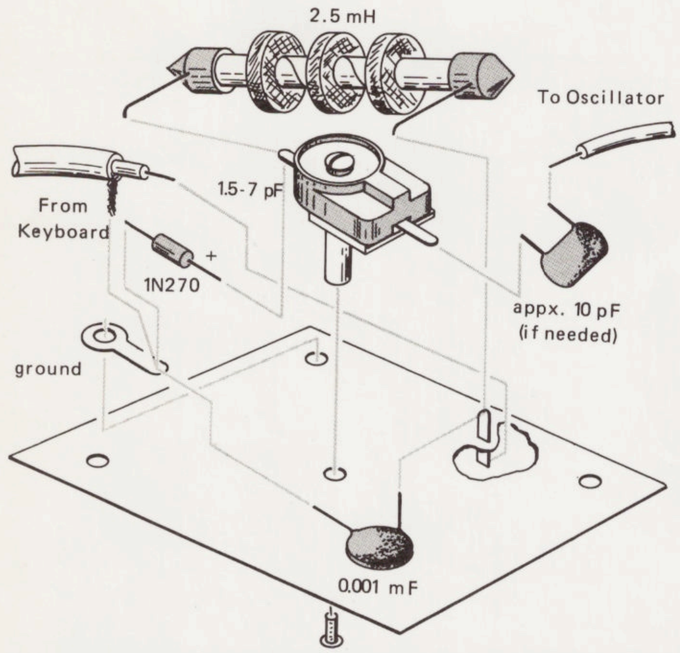
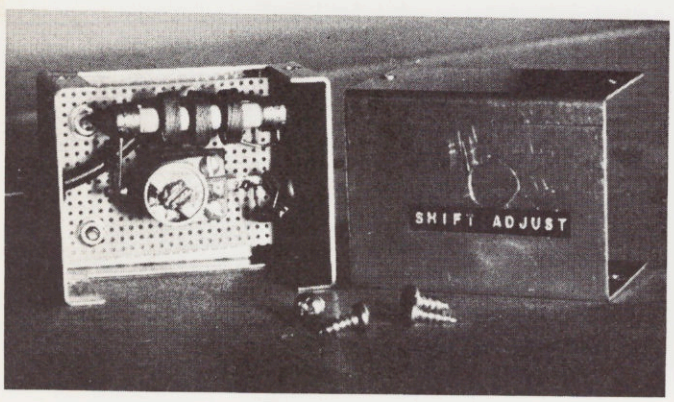


Fig. 8 – Pictorial diagram of the frequency shift keyer. Use this as a guide to construction along with the photographs of the keyer.



The keyer and its cabinet.

Call "CQ" in essentially the same way you would on c.w. You have, however, the option of adding a bit of personal data. Following is an example of a typical "CQ" as sent over RTTY.

(C.w. identification: K2VG)
CQ CQ CQ CQ CQ CQ CQ CQ DE K2VG K2VG K2VG
CQ CQ CQ CQ CQ CQ CQ CQ DE K2VG K2VG K2VG
CQ CQ CQ CQ CQ CQ CQ CQ DE K2VG K2VG K2VG
IRWIN IN NYC IRWIN IN NYC IRWIN IN NYC
K K K K (c.w. identification: K2VG)

And that's it! Don't make it longer than that or you will be labeled as a lid.

After someone calls you, the QSO runs almost exactly as it would run on *phone*, except everything is printed out. The reason I emphasize 'phone is because c.w. abbreviations are gauche on RTTY.

For example, instead of typing WX HR CLDY, it is more acceptable to type out THE WEATHER HERE IS CLOUDY.

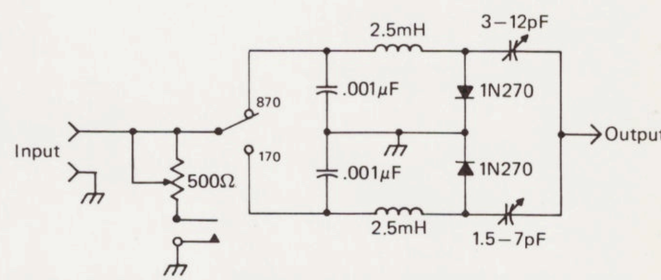


Fig. 9 – A frequency shift keyer switchable for 170 Hz or 850 Hz.

You will quickly pick up the procedures used in a RTTY QSO.

As a sub-population of the amateur community RTTY-ers are, without a doubt, the most considerate, helpful and friendly. Don't be afraid to make mistakes, don't be concerned about typing too slowly and don't be worried about inexperience. We were all that way at one time. The big difference is that RTTY-ers don't seem to lose their sensitivity to new-comers after having become old-timers.

Most RTTY activity is found on 40, 20 and 15 meters, although there is activity on other bands, a large portion of which appears on two meters. However, the bulk of the activity is on twenty meters and that band is a good starting place. The usual hang-out is between 14.075 MHz and 14.1 MHz.

On weekends you can copy all the big guns of RTTY, including those very talented artists who send their *oeuvres* over the air. ■