# RTTY

FG7XT, GUADELOPE—F.W.I.

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**NEWS OF AMATEUR RTTY**

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## HORSE TRADES

This page of the Bulletin is for use of amateurs who have RTTY EQUIPMENT FOR SALE OR TRADE and those looking for equipment to buy or trade. It is a free service and may be the means of getting someone on the air.

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**WANTED:** Model 14 type keyboards, K8VDU, 2918 Langfield Drive, Columbus 9, Ohio.

**WANTED:** Paper chute assembly, 90969 for model 26. K3GYS, 1610 South Iseminger Street, Philadelphia, Penna. 19148.

**FREE:** To anyone sending self-addressed stamped envelope—Schematic of FRXD. (Model 14 reperf-transmitter) W9YVP, 11001 South Pulaski, Chicago, Illinois 60655.

**FOR SALE:** Typing reperforator, Western Union type 5991, complete with stand and dust cover. Fair. $25.00 W2BVE, 834 Palmer Avenue, Maywood, New Jersey.

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**FOR SALE:** Model 14 TDs with sync motors. KL7MZ, SRA Box 4017, Spenard, Alaska.

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# A SECOND LOOK AT LIMITERLESS FSK DELECTION

**Victor D. Poor, K3N10**
**430 Center Street**
**Frederick, Maryland**

Frank Gaude, K6IBE, has done a great service to amateur RTTY with his exploratory work using variable threshold (slideback) detectors* in place of the usual limiter-discriminator type circuit. Under many A-B tests the K6IBE (TU-D) converter has outperformed limiter-type counterparts, however, some amateurs have observed, that under certain conditions the TU-D converter has a higher error rate than a limiter type. This is particularly true under conditions of high impulse noise (such as is characteristic of summer conditions on 80 meters), of fast-fade backscatter type signals, and (this is the most serious for the amateur) under normal conditions when the sending operator is a slow typist.

The fact that the error rate goes up rapidly when the signal is not tape sent is a clue to an important improvement that can be made in the detector. First of all, I think it can be safely asserted that the detector which produces the lowest error rate is the one in which the decision level (the voltage level where the slicer or Schmitt Trigger changes from MARK to SPACE or SPACE to MARK) is always at the most probable value for the "halfway" point between MARK and SPACE. Now "most probable" is a statistical thing and varies widely under certain conditions, but not all conditions. When a signal is tape-sent and there is not a great deal of impulse noise, then the dual slideback detector produces nearly optimum detection. The reason for this is that there is always a valid sample of the MARK and SPACE levels stored up in the detector signal level capacitors. In the event of impulse noise, the voltage stored in these capacitors is more or less randomly arrived at and does not represent a true value for MARK or SPACE. In the case of slow keyboard sending a SPACE signal does not come along often enough to maintain a valid sample of the SPACE level in the capacitor storage. As a result, the detector "thinks" that the SPACE signal has faded out during the period between keying. In other words, the detector decision level rests half-way between MARK and zero, rather than half-way between MARK and the most probable value for SPACE. Since, in the absence of keying, we don't know what the actual signal level for SPACE is, we must assume some value and the "most probable" level is the same as the MARK channel. This means that as time passes from the last instant of keying, the decision level should return to zero and not half-way between zero and the MARK detector output. Figure one illustrates this idea.

In the presence of heavy impulse noise, valid sampling of the MARK and SPACE levels is not possible and so we have to again fall back on the "most probable" value which again is zero (half-way between an unfaded MARK and an unfaded SPACE). In other words, *moving the decision level around to compensate for fading is good only so long as we can get a valid sample of the MARK and SPACE levels.* At other times the decision level should be returned to zero.

Several years ago Elmer Thomas of Page Communications Engineers, Inc., was faced with the problem of improving the error rate of an FSK channel and he developed a circuit called a "Decision Threshold Computer," (DTC). In short, it was variable threshold circuit similar to the TU-D circuit but, in the absence of better information, would return the decision level to zero. A patent was granted for this concept in 1961 and issued as patent number 2,999,925. The circuit I am about to describe was taken from the patent.

Figure 3 is a schematic of a detector circuit which can replace the slideback detectors in a TU-D converter and offers the advantage of improved performance under the signal conditions outlined above. Before trying to understand the circuit in Figure 3, let's look at a simpler circuit shown in Figure 2.

Leaving Rx out of Figure 2 for a moment, the circuit shown forms a dual clamp such that if you apply a keyed signal to point A the output at point B will swing evenly around ground. If keying stops, however, the output drops to zero as the capacitors discharge. Placing Rx in the circuit causes the output to rest at one-half the value of the input voltage. With Rx in place, the circuit can be seen to be equivalent to the dual slideback detector circuit in the TU-D converter.

Rather than add Rx, let's use a little more complicated addition to the circuit, namely R4 thru R9, CR3 thru CR6, and C3 and C4 as shown in Figure 3. Assume a signal at point "A" keying between —10 volts and +10 volts. Each time the signal goes to —10 volts, capacitor C4 is thoroughly discharged to zero. Since both C3 and C4 are large at typical RTTY keying rates, the capacitors do not have time to acquire significant charge thru R8 or R9 between the discharge intervals. Under these conditions, it is apparent that one end of both CR1 and CR2 still see ground and the dual clamp circuit works as before. Resistors R5 and R6 across the clamp capacitors are too large to have any effect during keying. Now, if during keying, one channel should fade, the dual clamp will maintain the signal centered around the decision level. If keying should stop (say at +10 volts) then C4 would begin to charge to +10 volts "lifting" one end of CR2 from ground causing the output to reset at the full +10 volts. In this way, the output at point "B" is equal to the full MARK value during periods of steady MARK providing maximum discrimination against impulse noise and sudden fades on the MARK channel when no keying is present.

In addition, a noise impulse is not likely to discharge C3 or C4 as keying would since the discharge rate is limited by R4 and R7 and a nearly full element time is required to change the stored charge.

With these improvements I have found conditions where copy that was unreadable with the TU-D circuit was greatly improved with the DTC cricuit. Even so, there are conditions where the DTC does not show any improvement over a limiter-distriminator and it will take accumulation of a lot more data to find just how far we have progressed.

As a practical matter, it should not be difficult to incorporate the circuit shown into an existing TU-D converter. I found that care had to be taken with the Schmitt Trigger to make sure that it sliced right at zero volts, both when going from MARK to SPACE and in going from SPACE to MARK. Follow the instructions in K6IBE's article, then test your adjustment by seeing if you get normal output from the TU with the input signal level reduced by about 100 times normal amplitude.

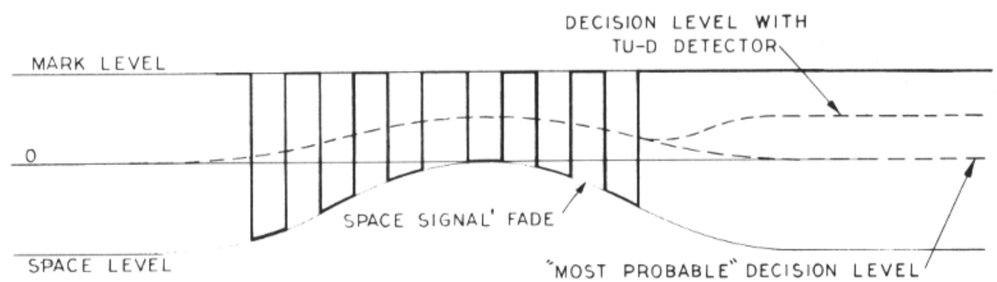


FIGURE 1

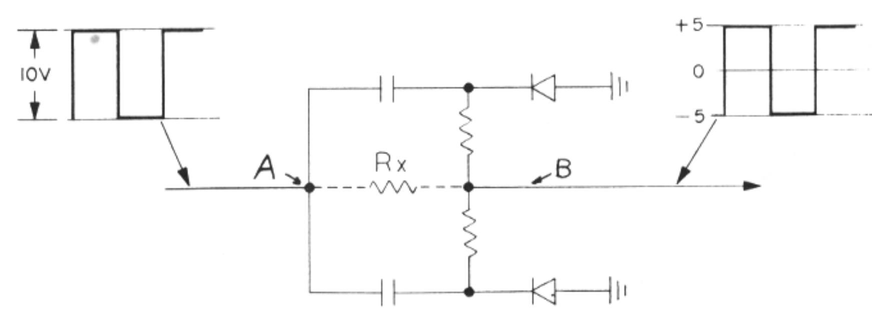


FIGURE 2

*Frank Gaude, K6IBE: "A New Approach to TU Design Using a Limiterless Two-Tone Method," RTTY June 1963.

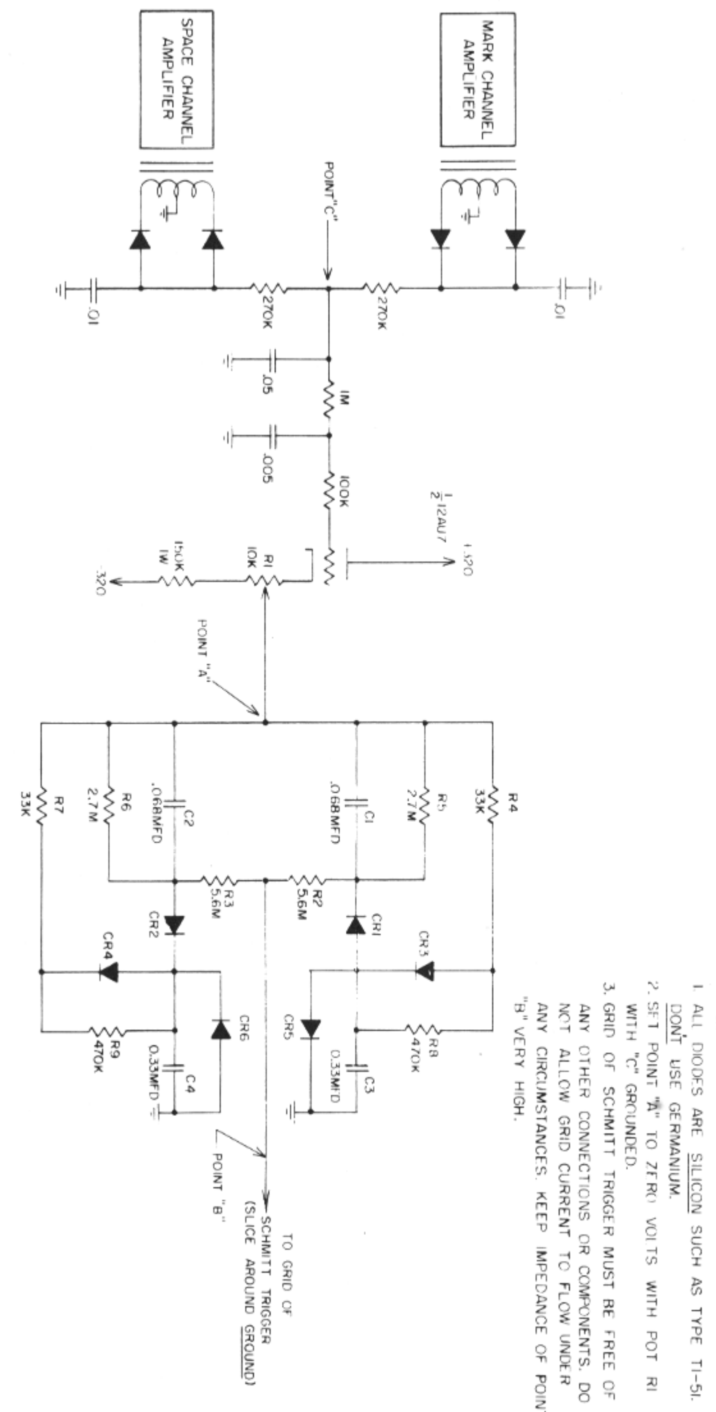


Figure 3
SUGGESTED CIRCUIT FOR CONVERSION OF TU-D TO DTC OPERATION



# A NEW APPROACH TO TU DESIGN USING A LIMITERLESS TWO-TONE METHOD

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Progress in radio teletype terminal unit design has been slow. This progress has probably been frustrated by ideas and equipments being essentially a carry-over from the wire services. Radio uses a medium which has properties different from a wireline and this single fact has not always been kept in mind in HF radio TU design. It is believed that this mental block is about to be broken and real improvements in radio TU performance can be expected presently. The design presented in this article will indicate a path which can be followed to realize a reduction in error rates that are experienced on typical HF radio circuits. A brief history of the design approach will be given so the flow of conceptual thinking can be appreciated.

The salient feature of the HF medium is that of selective fade. Wire lines do not exhibit this phenomenon. Let's define selective fade so that we all understand what is being discussed. Selective fade is the phenomenon of the reception of two or more tones whose amplitudes vary with respect to each other even though they were transmitted at the same power level. This ratio between the tone levels is not constant and is time varying. So for any given instant it is hard to say what the exact amplitude ratio is between the different tones or frequencies. This is a characteristic of HF radio and is almost always present. These relative amplitude fades between the mark and space frequencies causes serious trouble and results in errors in the conventional TU of the limiter-discriminator variety. These errors due to selective fade are produced even if the S/N ratio is high for both of the frequencies involved. Most amateur TU designs fall in the limiter-discriminator class—all but the "Gates" unit which deserves special mention. The new approach will turn this selective fade disadvantage for the conventional TU into an actual advantage and provide true frequency diversity reception.

Now let's see how the conventional TU gets into trouble when the two incoming mark and space tones are not of exactly the same amplitude. Figure 1 shows the waveform of the mark and space frequencies. If the receive bandwidth was very wide with respect to the on-off keying rate the wave forms would be essentially square, as they were transmitted. Now if receive filters are used ahead of the limiters in the TU, the waves are rounded and in the limit they become triangular waves. The limiters in the TU puts out the frequency that is the larger of the two. The transition from mark to space, called the zero crossing, occurs when the two tones are of the same amplitude. The output from the discriminator is determined by what frequency is driving the limiter. Now in figure two we see what happens when the two tones are not of the same amplitude. The result is bias in the output waveform which must eventually key the teletype machine magnets. This bias causes character errors if it is allowed to get large enough so that the machine selector is in the wrong place at the wrong time.

So we see that it is not enough to just have high S/N ratios to get error-free copy, but we must have the tones of about the same amplitude. During periods of selective fade it is best to have a widebandwidth ahead of the limiters so as to keep the waves square and thus minimize the bias introduction. This is in conflict with our desire to use narrow bandwidths to reduce random noise and QRM. The use of a "comb" filter ahead of the limiters makes things worse from the selective fade error introduction standpoint (W4EHU please note). Tests run by the author indicate that with a mark-space "comb" filter of 200 cps errors begin to appear when the tone amplitude difference is 18 db. Now such a ratio of tone difference is quite common on the HF bands and results with the "comb" will be poor if typical selective fade is present. This type of filter, of course, has its merits when there is no selective fade and QRM of the single tone or CW type is between the received mark and space frequencies. It is also useful when signals are very weak and steady.

It is interesting to note also that the so-called matched filter theory does not apply when the tones are experiencing selective fade. The theory requires tones of the same amplitude or filters which change their gain as the tones vary so as to keep the output to the limiter of equal tone amplitude.

Looking further into the characteristics of the conventional TU, we see that the unit requires that both tones be always at the discriminator output or errors will be produced. If one tone fades to the noise level while the other has high S/N ratio, errors will be made 25 percent of the time. And this is copy that is completely unreadable. Look at it this way: If the mark is good and strong,

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the output when it appears will always be of the correct polarity. Now if the space is weak or not there for a moment, the ouput will be arbitrarily mark or space. In other words, it will be wrong half the time. The mark was right all the time. So we get 25 percent element error for the case of RY's. The actual character error rate is much larger than this because a character is made up of seven element. The reason the space output was arbitrary was that the limiters ahead of the discriminator made the output random noise for the moment that the space was lost. The level of this noise is the same as the level of the good mark or a good space.

So now we see that the conventional FSK system is far from frequency redundant and has no frequency diversity feature. In fact it is worse than simple on-off keying because it requires both tones to be received, and received of approximately of the same amplitude. The probability of this situation occurring is only one-half as good as getting one tone through that is above the noise. These statements should cause quite some discussion! Just remember that two independent tones go into the noise during fading conditions twice as often as one tone would alone.

The things that I have discussed so far were known as early as 1938. But the philosophy of the wire services prevailed up to 1957, then H. B. Law of England succeeded in his crusade to turn to a better TU system that would take advantage of the characteristics of the HF medium. Credit must go to Law for his "sticking to his guns." When it is realized that one of the main reasons for going to narrow shifts is to combat the selective fade problem one suspects he is on the right track when the design turns fading into an advantage. The closer the two frequencies are, the more they will tend to fade together. This is a characteristic of HF. When they do fade together the situation is called "flat" fading. Of course narrow shift offers more than just selective fade reduction. But that is another story for another time.

The "Gates" TU in principle works differently from the typical limiter-discriminator type. It uses no limiters ahead of the discriminator, and the output from the discriminator is clipped and filtered and then goes to a keyer circuit that drives the printer magnets. As with all designs, the TU has a decision circuit which determines whether the tone is a mark or space. When the two tones are of exactly the same amplitude at the output of the discriminator the decision is arbitrary. This is called the "zero-crossing" point. If there is a little greater mark amplitude then the decision will indicate a mark until the space is great enough to overcome the mark amplitude. The point at which the cross-over from mark to space occurs in time is determined by the amplitude difference between the mark and space tones going into the TU. If the waveform is not bias free at the output of the discriminator, there is nothing that can be done to correct it later downstream. No amount of post detector clipping or limitering or filters can correct for this bias. Once the zero-crossing has been made, zero times anything is still zero. Now this is exactly what happens under conditions of selective fade in the Gates TU—keying bias is introduced, and the situation is the same as was shown in Figure 2.

The important improvement that the Gates TU could have offered is that when one of the two tones was lost because of selective fade there are no limiters ahead of the discriminator to amplify the noise to the same level as the signal. But the discriminator was not of a type that could automatically sense when a tone was lost or was low with respect to the other tone. The zero decision was not of an automatic adjusting nature either. Gates was so close. The author has demonstrated that the Gates unit can slightly outperform the conventional TU if the bandpass filters in the unit are wide enough to not round out the detected waveform too much. The better performance is only obtained under selective fade conditions. Otherwise the Gates TU gives essentially the same performance.

Now let's get down to the new approach. For those who want to know the entire background, it is suggested that they obtain the references at the end of the article. The new method has been given the name "Two-Tone" as contracted to conventional "FSK" converters. The two-tone method requires both frequency and amplitude detectors. No limiters are employed ahead of the detectors so as to preserve the amplitude information in the signal. Regular discriminator techniques are used to separate the mark and space tones int two separate channels. The amplitude of the energy in each of these channels is determined by what is called a "slideback" detector or something that does a similar task, "a ratio corrector." The slideback detector is actually two detectors in one and one slideback is required for each mark and each space channel. One part of the detector develops the keying envelope and the other part detects the fade envelope. These two types of information are added to give a signal that is symmetrically arranged around zero volts, the zero-crossing point. Figure *three* shows what the slidebacks do and how the two are combined to give desirable results.

What are these results? One now has true frequency diversity with only one tone being required to be above the noise to get a correct decision. One can copy using the mark frequency only or the space only. This is a great aid in dodging QRM. You can just drop the channel that has the interference in its passband. Only a small loss in performance results by copying with just one channel. Just what one would expect when you lose half



the transmitted power. Now the "comb" filter can be used all the time even when deep selective fade occurs, giving better over-all random noise QRM rejection. Now the decision circuit works on the channel which has the best S/N ratio, rather than the worse, as is the case with the conventional TU. It works with the channel that has the biggest signal automatically. When QRM happens to be the biggest of the two signals you can manually drop that channel with the QRM. Under deep selective fade conditions you can expect this two-tone limiterless TU to give error rates that are one-tenth that of a conventional limiter type. Under nonselective fade conditions it will be no worse than the conventional. It can be used to copy from the wide 850 cps shift down to the narrow 85 cps shift. This can be done with no adjustment in the circuit.

The entire philosophy of this new method is to take into consideration the characteristics of HF propagation and use it to advantage rather than having it work against you. Selective fade and QRM do not occur in wire line service and we should not necessarily think that the techniques used on wire are also optimum for the unpredictable medium that is radio.

Figure *Four* is the schematic diagram of a limiterless two-tone TU which is offered in the hope that the new method will be tried at many locations. The promise of the new system justifies a thorough trail on the ham bands by many experimenters. This particular design is one that has been worked on for the last six months by Bruce Harris (W5HCS) and myself. This particular slideback detector arrangement is the result of experimentation on about six different types by Bruce and the credit for its excellence goes to Dear Bruce. We hope that improvements will be made by each experimenter who chooses to give two-tone TU design a try. It is possibly the beginning of a new era, and by a little imagination great additional improvements over the conventional TU can be expected.

Since this not to be a blow-by-blow construction article, only a brief description will be given of the particular unit being offered as an example of two-tone techniques. The audio from the receiver goes to a line transformer which drives V1. The audio is also passed along to a WØHZR phase shift tuning indicator. This type of indicator is used because the selectivity of the coils in the plates of V1 is too low to get a usable "cross" type of display. The coils in the plate of V1 form the frequency discriminator portion and one is tuned to 2125 and the other to 2975 cps. Stagger tuning is employed to receive shifts narrower than the 850 cps. The input filter should be a bandpass unit that is wide enough to pass the shift that is being used. For best results a "comb" filter can be used. One output can go to each channel input through a SPST switch. These two switches can be used to drop the mark of the space channel as desired. V2 is straight linear amplification. The transformer in the plates form the slideback detector drives. C1 and R1 form the short time contant to follow the keying rate and C2 and R2 are the long TC for following the fade rate. These two voltages are in series. When the keyed tone suddenly goes away the long TC appears at the top of the detector output and is passed along as a voltage of the opposite polarity to the voltage created by the tone that just went away. In other words, marks are made out of spaces and vice versa. This is the reason that automatic copy can be made with only one channel since both polarities of information come out of one detector. When both tones are of the same amplitude the outputs from the two slidebacks reinforce each other. When one tone goes away completely the output is down to half value. This voltage is passed to the Schmitt trigger for the mark or space decision. It drives the keyer tube which drives the printer magnets. The keyboard and the VFO shifter is also in the plate circuit of the keyer tube. C3 forms a low pass filter at about 70 cps for waveform smoothing.

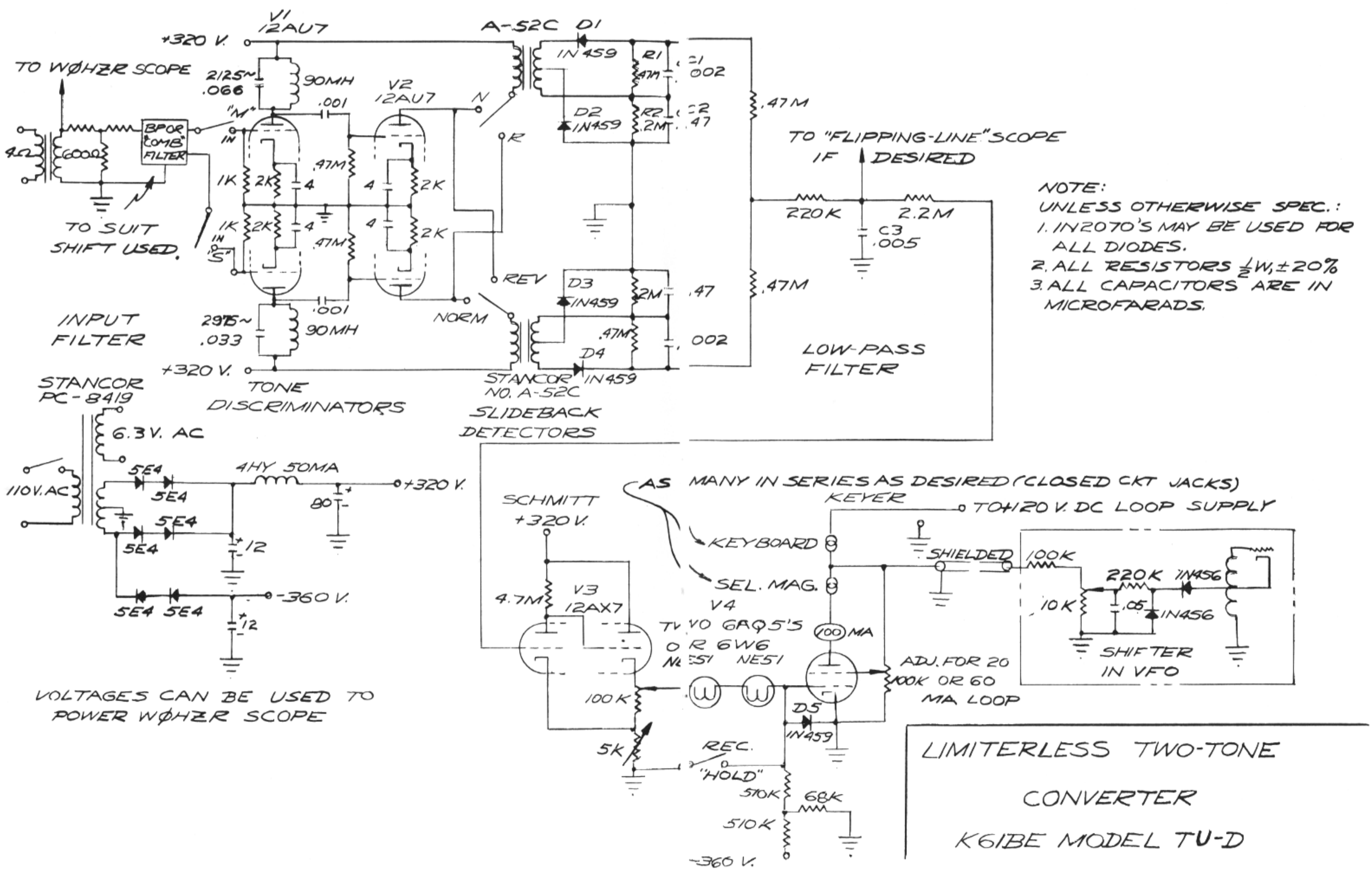
The Schmitt trigger is adjusted to change states at exactly zero volts to its first grid by adjustment of R3. Short the point at the top of C3 and change R3 until the keyer plate current is half its mark level value. R4 adjusts the neon bulb brightness and interacts a little with R3 so some back and forth adjustments will be required. It is all done with C3 shorted to ground.

The normal-reverse switch is to take care of the situations in which the transmitted signal is "upside-down."

One word of caution. Do not put so much audio from the receiver into the TU to make the amplifier stages clip. If these stages are limiting, one will not get the good weak signal performance that this converter is possible of giving. About two volts peak to peak at the grids of the first tube is the maximum that the unit can handle.

Now there you have the basis of the complete converter. It looks not much different from any other converter but it sure works a lot different.

In the necessarily limited test that the author has run, this two-tone converter has shown to live up to theory when the selective fade is deep and successive. In one such test, copying a commercial news-service station, the two-tone TU produced one-twentieth the character errors compared to a good conventional limiter-discriminator TU. Out of about 50 A-B comparative tests, the two-tone unit only once was worse than the conventional unit. In most of the tests the new unit was from two to 10 times better on an error rate count basis. Under selective fade conditions described by a Rayleigh function,




LIMITERLESS TWO-TONE CONVERTER

K6IBE MODEL TU-D

theory says that the limiterless two-tone should be 10 times better than the FSK type of converter. The reason that in practice this 10 to one number is not always achieved is that you don't always have selective fading of the deep variety, and also the slideback detector has a speed limitation on how fast a fade rate the long time constant can follow. This latter effect puts an amplitude bias in the decision waveform and results in more errors than there should be if the detector could follow the fade. Here is a good area for improvements. Whose first?

It should be noted that receiver AGC is helpful in keeping at least one of the two tones at a constant amplitude during fade conditions. The slideback does most of the remaining amplitude adjustments.

There are three hams who at present are testing the limiterless two-tone method of detection: W6NRM, W4MGT, and W5HCS. They would, I'm sure, be happy to discuss its potential with anyone on the air.

The author wishes to express his extreme gratitude to K5AUM, R. C. "Doc" Martin, for his catalytic action in regards to this article. As in some chemical reaction equations: K6IBE plus typewriter and paper, without catalyst, yields no TU article.

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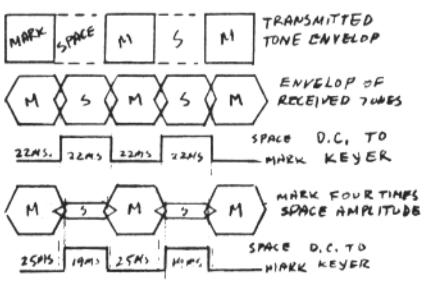


FIG. 1 SLIGHT BIAS INTRODUCTION DUE TO WIDE FILTERS & SELECTIVE FADE

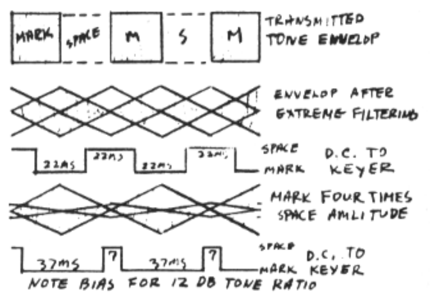


FIG 2. BIAS INTRODUCTION DUE TO FILTERING WITH SELECTIVE FADE

*Circuit Pages 8 & 9*

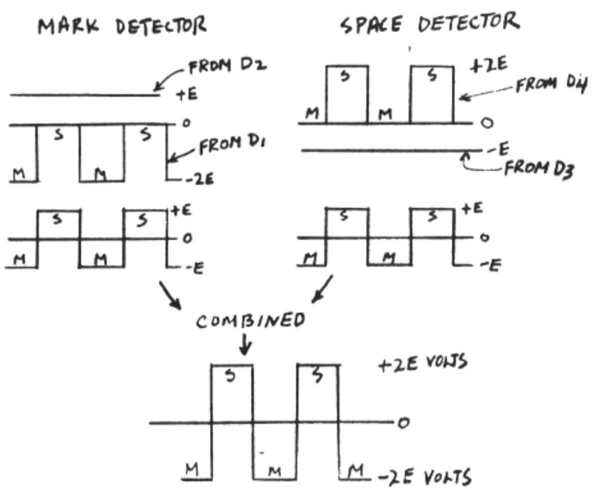


FIG. 3 OUTPUT DETECTOR VOLTAGES VS. TIME (SLIDEBACK)



# "WHAT IS THIS TWO-TONE DETECTOR?"

## MARK III/IV MODIFICATION TO TWO-TONE RECEPTION

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Over a period of years, the Mark series of terminal units employed the classical FM limiter-discriminator circuit in their front ends. Likewise many amateur TU's have been of this design. Generally speaking, performance has been quite satisfactory, especially when multipath or selective fading is not severe. It is noteworthy that all commercial RTTY gear manufactured in America, to the writer's knowledge, continue to use the limiter-discriminator system.

As K6IBE has so well pointed out in his interesting paper[1], reception of RTTY signals mutilated by multipath introduces difficulties. Multipath causes independent fading of both components of the frequency-shift keyed signal to the extent that oftentimes the *mark* may fade out completely yet there is a strong *space* coming through; likewise vice versa. The classical limiter-discriminator arrangement detects the fade-caused absence of mark as a noise, and therefore keys the loop on that basis—obviously resulting in garble. Hence we must consider ways and means of detecting *either on-off keyed mark alone* or *on-off keyed space alone* as the case may be and thus recovering the intelligence from either to properly key the loop. Several designs leading to this have been worked out by various amateurs. The Gates TU is one partial approach[2]; this was mentioned by K6IBE. K6ZH/W6AEE had another design[3] that performed quite well some years ago; they called it "semi-diversity". W6OWP's "single filter TU" is another such approach[4]; in fact F. C. Bartlett had championed the cause of MAB (make-and-break) RTTY on the low frequencies in the early days of the amateur RTTY movement.

One point is here emphasized. *Mark is the complement of Space;* i.e., one is the mirror image of the other. Intelligence is available from either one alone; all the detector needs is the ability to recognize and take advantage of the redundancy inherent in these alternately keyed components—should one or other be missing temporarily due to propagation conditions. In effect this detector should be able to copy mark alone or space alone—automatically—as well as taking both. This concept leads to separate detection channels for both tones. This is called "Two-Tone" in contrast to the demodulation method using FM principles. The new method preserves the redundancy available in the two parallel channels of the FSK signal and provides the added benefit of *Frequency Diversity Reception.*

Over a period of many years studies and experiments have been made on alternative methods of receiving RTTY signals on the high frequency bands—mainly by workers in England. As far back as 1938 certain British engineers noted the selective fading characteristics of FSK signals on the HF bands and they proposed independent detection for both components—however due to the then-existing state-of-art there were some technical difficulties. It remained for H. B. Law and his co-workers to explore this in detail in a monumental series of articles in a British engineering journal[5]. During this period a special on-off tone detector of high flexibility to cope with varying tone amplitude due to QSB was described[6,7]. This circuit actually has two definite time-constants; one to follow the signal-intelligence, and the other to follow or "compensate" the fading pattern on the signal. Properly arranged, this detector would deliver an output voltage having definite positive-or-negative polarities as signalled by the on-or-off tone coming through its channel. Fading is compensated for by having one-half of the signal voltage subtracted (but not actually lost) by the "slide-back rectifier" portion of the system; this subtracted voltage is then used to deliver a reverse polarity indication to the loop keyer during absence of tone.

Such a detector is shown in Fig. 1. This should be self-explanatory; it shows the slide-back detector arranged for on-off tone reception. Signal diode $D_1$ rectifies and applies to load $R_1C_1$ a voltage output corresponding to the input tone signal. Slideback diode $D_2$ rectifies one-half of the input tone amplitude to charge up $R_2C_2$; as the figure indicates the output from this load is of one-half voltage and of reverse polarity to that from the first load; both loads being in series. $R_1C_1$ time-constant is short, 1 or 2 milliseconds at most,

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1 Limiterless Two-Tone TU, **RTTY,** June 1963
2 Gates TU, **RTTY,** October 1954
3 K6ZH/W6AEE TU, **RTTY,** May 1960
4 W6OWP TU, **RTTY,** March 1956

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5 Allnatt, Jones, Law, etc.: Six papers in **Proceedings of the Institution of Electrical Engineers,** Vol. 104, Part B, 14, March 1957
6 Beard and Wheeldon: A Comparison between Alternative HF Telegraph Systems, **Point-to-Point Telecommunications,** June 1960
7 Dames and Tibble: A Flexible System for Receiving F.S.K. Signals, **Electronic Engineering,** November 1962

so it follows faithfully the on-off tone transitions as indicated in the second waveform diagram. $R_2C_2$ time-constant, however, is considerably longer—of the order of 132 milliseconds—so we have as a result the third waveform diagram. Combining both outputs algebraically we obtain the result in the fourth waveform diagram. (Please note—the word limiter here refers to the clipping action in the loop keyer circuit; not audio amplitude limiting.) The final output, applied to the teleprinter loop, is shown last.

Fading on this single detector is compensated for by diode $D_2$ so that no matter how much fading there is, definite positive and negative swings are delivered corresponding to the tone on-off modulation. Effect of fading is merely on the positive going or negative going voltage levels with reference to the ground point. The "limiter" in Fig. 1 is the zero-axis crossing detector, whether of the saturated dc amplifier system (Mark III/IV) or of the Schmitt trigger of K6IBE's TU-D. Hence it does not matter how much swing or "on-off" levels are concerned as long as there are definite and equalized swings either side of this zero-axis to operate the loop keyer.

The above arrangement is an on-off detector system, for one tone coming through on the channel. Such a circuit enables make-break detection of an incoming RTTY signal tone and by itself has been found to be remarkably effective—using a simple circuit and with a minimum of parts. To receive both tones, two such detectors are arranged and polarized so that when both tones are coming in equally good, the two detected outputs reinforce each other to yield a doubled voltage swing to the loop keyer.

Time constant on $R_2C_2$ is a matter for argument; it will suffice to mention that the longest uninterrupted portion of a teleprinter character is 132 milliseconds, corresponding to the BLANK key. If we make this time constant value in our design, the slideback voltage will decay to 37% of full charge at the most during ordinary RTTY operations, and much of the time the slideback output will be almost fully charged—following faithfully the fading pattern in the incoming signal tone concerned. Fading rate varies, however, but is generally appreciably longer than the 132 millisecond value so that the fade-compensator diode-$R_2C_2$ load keeps track of the fade amplitude variations for most practical purposes. VOILA, we have a tone detector that will key a teleprinter loop properly even if the input tone level is smoothly and relatively slowly varied from say 1 volt to 100 volts while it is being keyed by the teleprinter intelligence.

Certainly, the single tone by itself is not going to give perfect reception; especially if the tone concerned should disappear entirely for as long as a few seconds. No tone for that period implies disappearance of the signal concerned; this will cause noise to appear in the detector output as shown in Fig. 1. However! We may have a good strong tone coming on the other side, capable of carrying the information on through the RTTY system. Hence we use two separate slideback detectors, each driven by each of the Mark and Space tones, placed algebraically opposite and in series with each other so that their outputs are combined to deliver the final keyed information to the loop keyer. This is the two-tone system, and as a result of this independent detection of either mark or space or both automatically combined, we have the added benefit of FREQUENCY DIVERSITY RECEPTION. This, with just one receiver, relying on the redundancy contained in the Mark and Space complements of the received FSK signal.

With such a modification, the Mark III/IV system was found to yield much better results on reception of multipath-affected signals—to the extent that error rate was as much as 1/20 or 1/30 that of conventional limiter-discriminator reception. As an example, during tests, the unmodified Mark III was used to feed into one teleprinter machine, whilst the two-tone Mark IV fed into another machine. Both TUs were driven off the Drake receiver's audio output. On certain distant signals, amateur and commercial in the 14-15 Mc/s range, the two-tone system delivered considerably superior copy. Over a ten minute period, 60 hits and quite a few aggravating false carriage returns with resulting overlines were observed on the limiter-discriminator copy. Only 2 or 3 hits and no false carrets on the two-tone copy. Quite a difference!

## Conversion of Mark III/IV to Two-Tone

The modification is very easy to incorporate into existing Mark III/IV[8] terminal units, and should be applicable to any other discriminator-type TU's already in use. All that are needed is separation of the two tuned channels of the old discriminator so they, together with their respective signal diodes and loads, operate independently of each other; and the addition of "fade compensator" diodes and loads so they are driven by half-voltages available from the appropriate tuned circuits. The additional parts are easily accommodated inside the Vectorcan that houses the old discriminator.

Figure 2 details the changes needed to convert to two-tone. Here the separated Mark and Space channels are combined in series-aiding by tying together outputs from their respective fade compensators. Output from this entire system is obtained from two points alone, marked M and S. This series scheme for both channel detectors was chosen because it was desired to obtain a two-point connection which is readily accepted by the present input FSK sense reversing switch in the TU circuit. This incidentally keeps available signal output swing at a maximum into the zero-axis crossing detector (dc amplifier), and simplifies the modification procedure; all the work done is inside the plug in can.

The half-voltage is obtained by making use of the tied-together centertap connection of each toroid. It is recalled that the 88 mh toroid consists of two windings, having equal characteristics, wound on a core; and during tuneup these two windings are in series. Their tied-together ends provide a convenient half-voltage point for the fade-compensating diode-load circuit. In both channels, the signal diode portions are left as in the original discriminator circuit, with their 16K and 27K loads. The fade compensator time-constant RxC is made up using 100K resistors with 1.7 mfd 125-volt working tantalum capacitors, yielding a value of 170 milliseconds. The diodes are of the same silicon type as used in the signal diodes.

Further, the oscilloscope indicator had to be rewired to isolate the DC swings off the fade compensators from the CRT plates—which otherwise will affect the display so it becomes displaced downwards and to one side from center of screen. Shown are isolating networks, which can be of .001 mfd and ½ megohm size. The original Mark IV display is thus essentially unaffected and very useable for tuning in HF band signals. The neutral of the 'scope system is connected to the interconnecting loop between the fade compensators whilst the AC from the tones go to their respective deflecting plates from the hot-ends of the tuned toroids via the aforementioned dc isolating networks.

No other changes in this "ex-discriminator" portion are necessary for the present time. The input link turns remain the same as in original specifications; the rest of the circuit bearing on the plug in can's socket is unaffected.

## Limiterless Operation during Two-Tone Reception

There is one important point that was not previously mentioned in this article. The two-tone method demands that all amplifiers feeding into the slideback detector system be operated in a linear mode, without any limiting. The limiter portion of an FM system is inherently very noisy on no-signal due to excess gain being applied in that stage. This will degrade the performnace of two-tone reception on a selective-fading signal because the redundancy feature is impaired due to the clipping or limiting imposed upon both tones as well as on any noise coming through. Both channels must be as independent of each other as possible; as if two independent sharply selective receivers were used.

Hence for this modification we can accomplish limiterless mode in one or other of several ways. The receiver audio gain is reduced to such a level that the input tone signal level is a few microwatts; this is easy to accomplish by referring to the tuning indicator. Turn the gain down until the mark-space traces just almost decreases; then you are operating on the edge of no-limiting. The receiver is set on AGC fast-attack slow-release (SSB mode) and its RF gain is advanced full on; the AGC serves to regulate the audio level into the TU.

For easier control on input level, the TU's input amplifier circuit can be modified by introducing negative feedback to reduce its excess gain so it now operates in a linear mode. The change is noted in Fig. 2 notes. Another modification is to simply disconnect the 10 mfd 25 volt capacitor from across the input 12AX7 triode cathode resistor; this makes it less sensitive and readily controllable as far as input level is concerned.

The bandpass filter in the Mark III/IV system continues to be useful. It defines the passband so that only the RTTY signal with its sidebands are admitted, and adjacent channel signals are rejected insofar as its characteristics (bandwidth) permits. Of course additional passband selectivity as the receiver may have in its i-f circuit is helpful and a necessity. We shall discuss this.

## Receiver Adjustment and Operation with Two-Tone TU

The Drake 2B receiver, in constant use at W6NRM on the amateur RTTY circuits, continues to prove itself an extremely versatile and useful instrument. Two very desirable features so necessary for optimum RTTY working are incorporated in this receiver—adjustable passband tuning with 500 and 2100 cps bandwidths (6 db), and fast-attack slow-release automatic gain control.

The passband tuning is quite useful because it permits optimization of the received signal's channel so it aids in proper driving of the TU insofar as mark and space components are concerned. Furthermore, the ability to switch between 500 and 2100 cps bandwidths permits automatic operation of the two-tone TU on mark-only or space-only mode without any particular problems in case of QRM on one component or the other. Adjusting the passband tuning permits peaking on mark or space as required.

The AGC must be on fast-attack slow-release, obtained by setting switch to "SLOW AVC". This introduces just about the right amount of delay in release so that noise is effectively suppressed during monetary absences of either mark or space tone, yet the TU continues to turn out clean copy. Slow AVC is even more necessary when operating single-tone reception using the sharp selectiv-

[8] Mark IV TU, RTTY, March 1963

ity position. Fast AVC is too fast; it permits noise to come right in as the receiver sensitivity increases in between signal elements.

The audio gain control is adjusted as explained previously to obtain no-limiting in the TU, while the RF gain is advanced full on. While it is true that this particular two-tone Mark IV must be operated in a nonlimiting mode for reception of RTTY signals affected by multipath, it can still be operated as a conventional FM system merely by advancing the receiver's gain control so it limits. This enables ready comparison between limiting and limiterless modes, and for some local circuits it may be more convenient to operate that way. The Mark IV's automatic mark hold system works quite well, although during two-tone reception its threshold control must be advanced a little more because of the somewhat reduced swing available from the modified ex-discriminator circuit—amounting to some 75 or 80 volts as against the 120 volts available from the straight discriminator. There is a loss, due to the addition of the resistors in the fade-compensators and compared to the resistances in the TU's low pass filter network; however there is plenty of signal swing available and the zero-axis crossing detector responds as usual to approximately 1-2 volt change about its zero axis. This compares with 75 volts swing—hence no particular problem.

## Concluding Remarks

The slideback detector as diagrammed in Fig. 1 can be modified in several ways yet provide the necessary ratio-correcting function. The circuit in Fig. 2 works the same way; merely a rearrangement of coil driving taps. K6IBE's detector circuit, driven off audio transformers, is quite identical to Fig. 2; however there is a difference. The other circuit is a three-point output system using a pair of resistors for final combining into the low-pass filter-Schmitt trigger stage, while the Fig. 2 circuit is a two-point output arrangement. Hence K6IBE's diodes are reversed in polarity as indicated. There is a loss of dc swing in his circuit as a result of those two combining resistors, however his zero-axis crossing detector functions very adequately. One might say that the TU-D uses parallel combining of the mark and space dc outputs while the modified Mark IV uses series combining. No essential differences exist except for the increased loss of voltage in the former-mentioned circuit. All in all, these circuits should provide ideas for those who wish to experiment further with two-tone modifications or adaptations to their existing TU's.

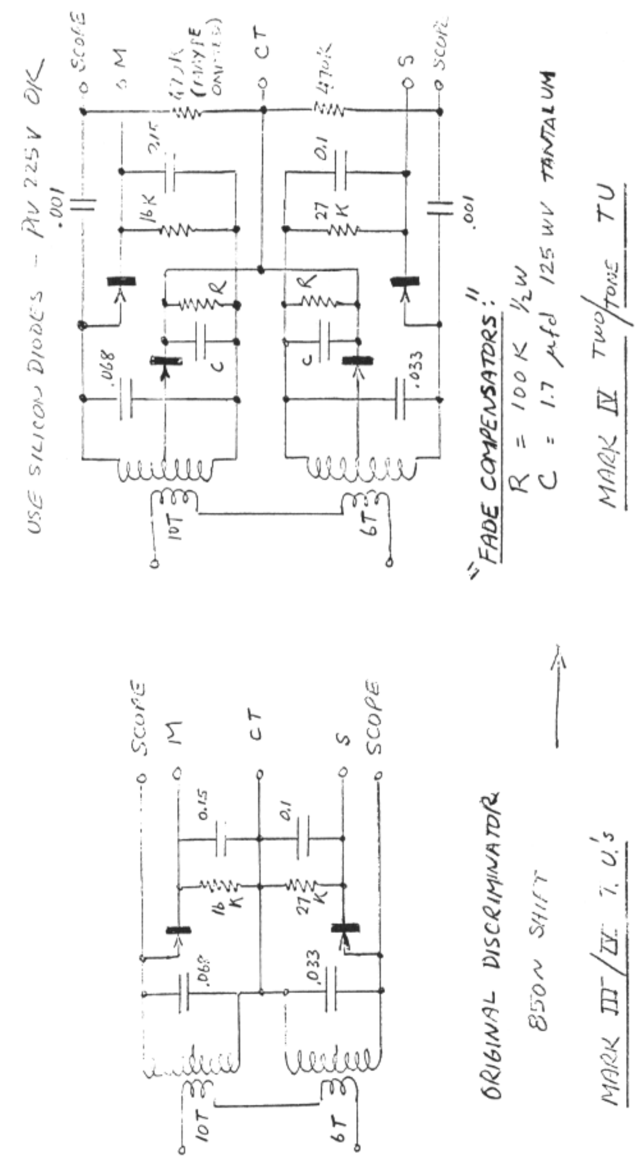
A word about bias measurements will not be amiss. On a normal RTTY signal with little or no multipath, the two-tone keying has been found to be zero bias. Coil tapping and accuracy of half-voltages seem to be relatively uncritical; hence the two-tone detection system is relatively quick to install and requires practically no alignment as far as voltages are concerned. Furthermore, it was found that this new system is even less sensitive to effects of detuning on a received RTTY signal; in other words, hardly any bias is introduced should the signal drift to one side or the other. This is also true for variations in dc output total swing—with markhold switched to "out", the TU continues to operate on a signal that is hardly visible on the W6AEE display or that hardly wiggles on the flipping-line display. Normally the gain is set so that the equipment just barely limits; this permits use of automatic markhold.

However, on single tone reception, whether mark or space only, a certain amount of bias is introduced—amounting to some 5 to 7 percent spacing bias on space-only reception and (whoops) 10 to 15 percent marking bias on mark-only reception. Slight adjustment of coil tapping or control on half-voltage in one way or other does not seem to affect this condition. Inspection of the tone waveform as keyed on an oscilloscope shows differing rise-times and decay-times, and arbitrary setting of zero axis crossing at exact midpoint between full-tone and no-tone (75 volts and 0 volts respectively) shows definite bias when the alternate reversals from letter Y repeated are injected. This is a function of the response characteristic of the single-tuned toroid. In fact, H. B. Law has covered this point very well, and indicates requirement for special bandpass filter carefully designed for equalized rise-and-decay times for handling single on-off keyed tones into the detector system.

All in all, a well adjusted teleprinter tolerates moderate amounts of bias, and during operation this present Mark IV modification has showed definite improvement in reception of signals affected by multipath. There has been no occasion, so far as known, that the old FM method would be better than two-tone. On most signals, relatively steady or affected only by flat (Rayleigh) fading, both systems work about the same way — yielding perfect copy. Only on such difficult circuits as affected by multipath does the two-tone come into its own. Incidentally, multipath also may have timing differences introduced between mark space components amounting to 2 or 4 milliseconds; this is extremely bad on conventional FM reception method because the limiter receives both tones simultaneously during these critical periods—resulting in an indecisive output to the loop keyer. The limiterless mode neatly sidesteps this objection and introduces, as mentioned, the benefit of frequency diversity reception.

So—the whole field of terminal unit design is now wide open as a result of introduction of two-tone techniques. What shall we do about proper filters for equalized rise-and-





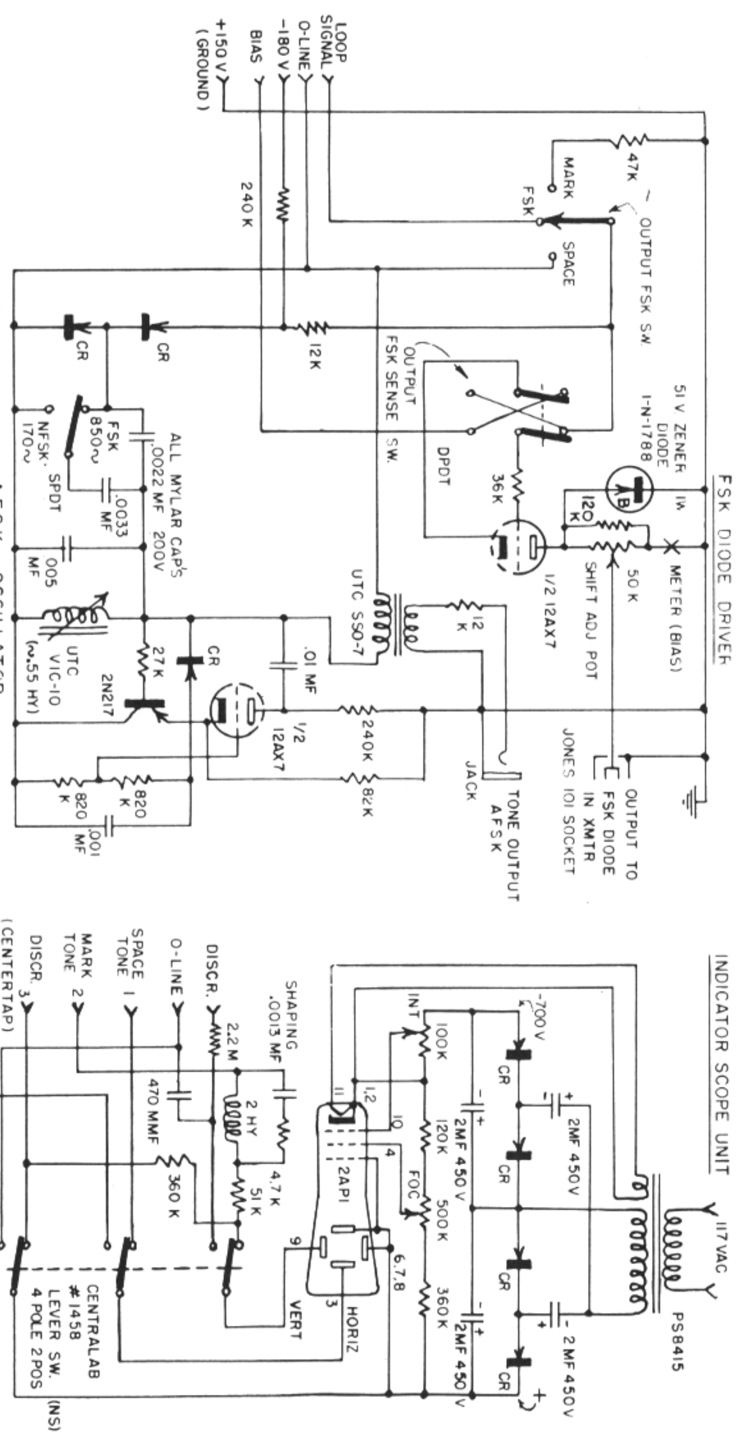

NOTES: OPERATE TU IN LIMITERLESS CONDITION

(1) By reducing audio gain in receiver until scope pattern just decreases in amplitude. Or,

(2) Add .068 mfd and 47K 1/2 W resistor in series between 6AQ5 plate and 1/212AX7 cathode (top of 3K resistor; disconnect 10ufd 25v capacitor); this gives negative feedback and reduces gain.

FIGURE 2: MODIFICATION OF MARK IV SYSTEM TO TWO-TONE

R.H. WEITBRECHT - W6NRM
June 24, 1963



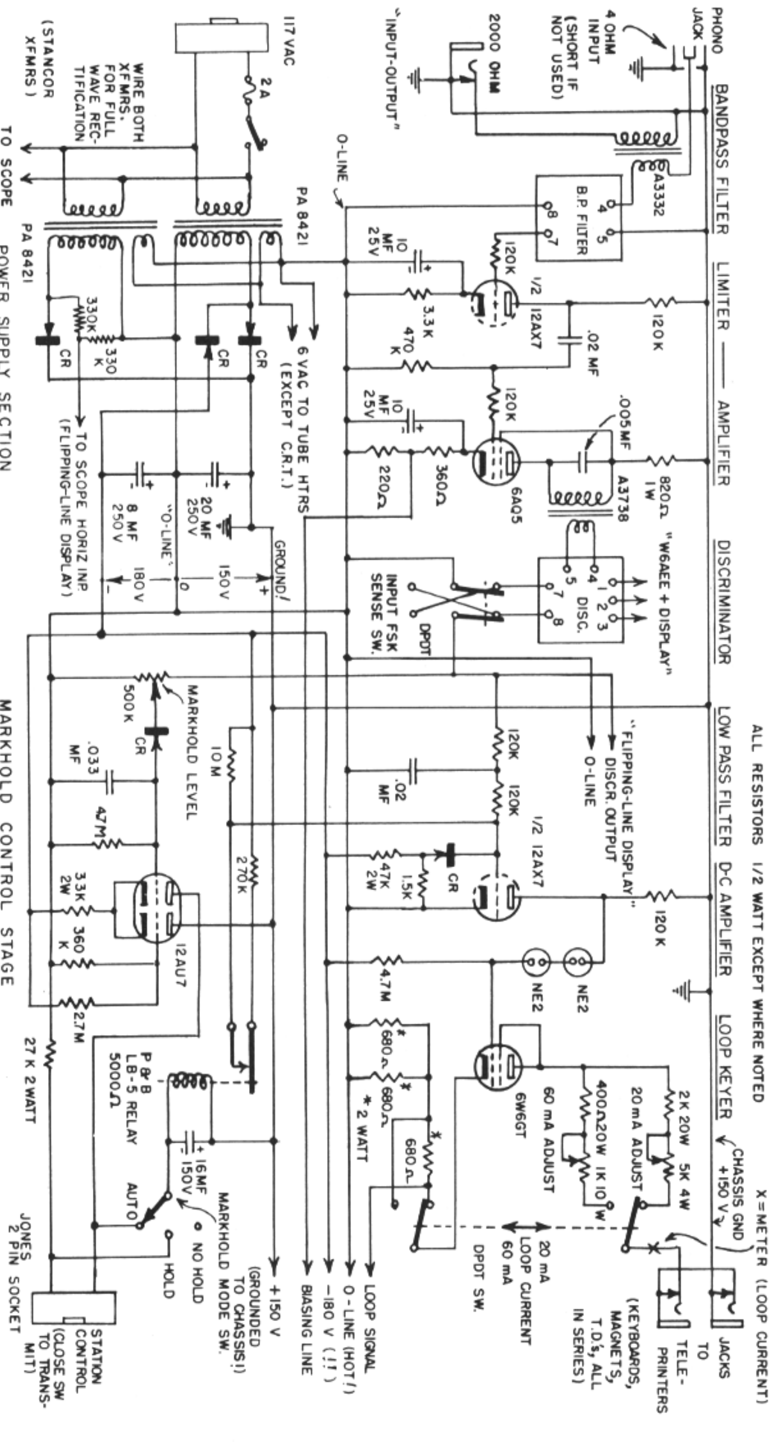

W6NRM MARK FOUR TU

TRANSMITTING AND SCOPE PORTION

FIG. 3

**REPRINTED from March 1963 RTTY.**






RECEIVING PORTION

FIG. 2

TWO UNITS BUILT - WINTER 1961-62

MARK FOUR TERMINAL UNIT

BY R.H. WEITBRECHT - W6NRM

# DX-RTTY

**Bud Schultz, W6CG**
**5226 N. Willmonte Avenue**
**Temple City, Calif. 91780**

Howdy Typers:

Excuse me if I start this month's effort with an apology. For the past six weeks things have been in such a turmoil here at the DX desk that I haven't had a chance to come up for air! For about three weeks your DX logs for the SS really kept things buzzing. Then, as I was getting reorganized for a nice newsy column, the sad news of the Presidential assassination came thru followed in order by a major kidnapping story and finally the Baldwin Hills Dam disaster has kept this reporter at work almost around the clock. Just as though all this wasn't enough, my rig blew up and the XYL is sick abed which means I am chief cook and bottle washer so if this cloumn leaves something to be desired please be tolerant with your criticism. The mail is stacked up on the desk here until I cannot see over it. Let's open a few off the top and see whats going on–okay?

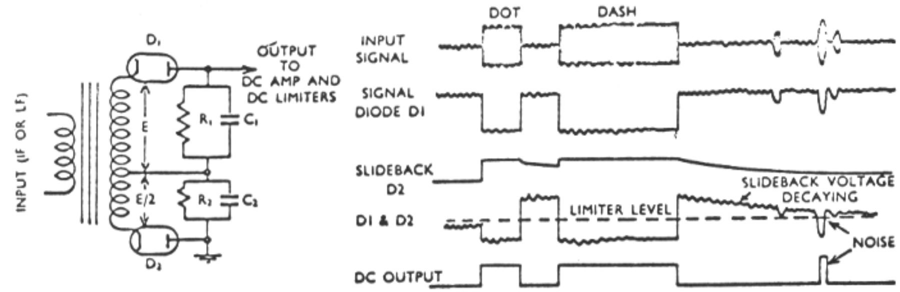
At long last here's a fine newsyletter from Bill Brennan, G3CQE who is in the process of moving to another part of England. Here's a few excerpts: ". . . I am still living in a boarding house here in Wachet . . . I am more or less stuck here as a prisoner in this one room . . . I have no radio facilities of course." Bill points out that his family is over 300 miles away and it takes him a good nine hours driving time over bad roads to get home to see them. He expects to be in a new home by the end of February and then some RTTY activity again. Bill says the working RTTY station at the RSGB Show was a howling success. To quote again: "There were so darn many people around the station it was near impossible to get near it!" He also points out the interesting fact that the DL's have finally got a bit more freedom of band space for RTTY. Their new RTTY frequencies are 3575-3625 kc, 3725-3775 kc, 7025-7050 kc, 14075-24110 kc, 21075-21125 kc, 28100-28150 kc and 145.8-145.9 Mcs. This is indeed a big advance for the German typers. Bill winds his letter up by advising that he is only 15 miles across a channel from GW land and is having pow wows with them about getting some RTTY activity going there.

Here's a fine letter from John, KR6BE who says he is happy to announce he is again on the air from Okinawa. He is running 150 watts and a long wire antenna. To quote from John's letter: "I plan to remain on Okinawa until May or June of next year so pass the word to the boys to turn their beams in this direction once in awhile. I am still trying to raise more interest in RTTY here on Okinawa and at the present there are about 5 stations with the capabilities." If you need Asia for WAC this is a real good bet.

Next on the stack is a long letter from Bruce, ZL1WB. He proudly announces he has managed over 210 QSO's on RTTY in 1963 (Thru October) which is a new all time high for him and not a bad total for even a Stateside typer. Bruce says band conditions were very poor during the Contest week-end but the European boys had wonderful signals down there during the entire 48 hours. He says he heard me very weakly during the SS and wonders if I had my final turned on!! I had it turned on Bruce, but there was nothing coming out of it!! Bruce says the only Stateside station he heard on Forty was W8CLX. Here's a quote from ZL1WB: ". . . building another rig using 4-125's and want to put the 4x250B on 144 Mc/s in readiness for Oscar III. Gave the model 15 its 50,000 mile oil change after the SS and am busy mowing the lawns at 'belly-acres'." Bruce enclosed a clipping from an Auckland paper containing a story and photo of ZK1BS and XYL who are now retired and spending some time in N.Z. The article points out that the ZK1BS'es are on their way to the Bahamas so perhaps we can look for some more bauds from Bill under a VP call in the future.

Next on the pile is a thick five page, close spaced, effort from Eric, VK3KF, with oodles of interesting material for a DX column. Eric suggests that a second DX contest in the Spring months might have merit. He feels (and I am in strict agreement with him) that the handling of a World-Wide Contest is too strenuous for one group to attempt more than once a year. For this reason he suggests that some other organization (preferably outside the States) take over the administration of a second yearly brawl. With this in mind he is polling the membership of the S.P.R.A.T.S. to see if he can get enough support for a DX contest in the Spring of '65. Eric further suggests that in the up coming years other TTY Societies in other Foreign Countries might like to take over the sponsorship of a second yearly DX Contest. It seems like an excellent idea to me but it depends on what all of you DX'ers think about it. Eric says he has been keeping skeds with Rene, DL3IR and one weekend he had a three-way contact on RTTY with DL3IR and 5A5TR. He points out that the contact with 5A5TR made his






*Slideback detector for AM system*

*Slideback detector waveforms*

Fig. 1 (From article by Beard & Wheeldon, Point-to-Point Telecommunications June 1960)

decay times? Perhaps the pi-filters will work fine; this is being investigated as more TU's are built and evaluated. It appears that TU's can be simplified even more yet be considerably superior under all possible conditions than FM designed gear can ever hope to be when operated on the HF bands.

I would like to express my gratitude to W2PEE for evaluating this Mark IV modification and corroborating my findings. The experiments by K6IBE, W4MGT, K5AUM, W5HCS and others have indeed been a source of inspiration; likewise the continued interest in these techniques by W6AEE and WA9IBB (ex WB6ABF) should be mentioned.

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third complete WAC-RTTY and he is still operating without a P.A. Fine work, Eric!

Well, we have run out of space already and I have just barely touched the very highest spots in the mail bag. It's really too bad all of you can't read these fine letters in their entirety. I know you would find them as interesting as I do. Letters like these serve as a most ample reward for the time and effort required to put this monthly effort in print. Thanks to all of you for your help. Next month's issue will contain the complete rundown on the SS results. (notice how careful I was to avoid any reference to the winners this time?)

It's time to start dinner, wash the lunch dishes and give the XYL her medicine so if I can find my apron I will be off and away. See all of you right here next month!

73
Bud W6CG

P.S. Don't forget the dates for the 1964 Anniversary SS contest. Over week end of February 15th, 1964.