RTTY Demodulators

You Can't Work 'em If You Can't Hear 'em

old amateur radio proverb

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The popularity of RTTY in amateur radio has increased greatly in the past 10 years. This growth is due both to the availability of commercial equipment for RTTY and, more recently, to the interest of many of us in hobby or personal computing. The RTTY hobby no longer requires that the beginner be mechanically inclined and willing to wrestle with and maintain the old monster teleprinter machines. These machines are still around for those of us who like mechanical gadgets, but it is usually far easier and more attractive for the beginner to start out immediately with a video terminal and not have to fight gear ratios, deafening noise levels, and drops of oil everywhere!

The typical RTTY station used to be an electro-mechanical "nightmare" of machines, paper tape, and wires—millions of wires (or so it seemed). All self-respecting RTTY operators had two or three printers, tape machines, strip printers, loop supplies too heavy to lift, and, of course, several demodulators. It was often said that an RTTYer's favorite winter sport was rebuilding the demodulator. We all had several "ultimate' units in the works, and even finished some of them!

The typical RTTY station of 1983 is something entirely different. The "modern" station is unbelievably compact by 1960 standards and may even take up less room (and power) than the transmitter and receiver. Gone are the stacks of mechanical gadgets and maze of wires we all recognized as the mark of the "true" RTTY devotee. Printer paper has been replaced by a video screen (usually green, if you're "cool"); paper tape has been replaced by a few plastic parts called RAM integrated circuits. Our keyboards are now "educated" so that we no longer have to remember to always type LTRS and FIGS keys. A slightly different type of integrated circuit allows us to call-up and send our call sign and that of the other station at the press of a key. Other "memories" store our "bragtape" (still called that). We even have "electronic mailboxes" (sometimes called "MSO's") that will store and replay whole messages upon command. RTTY has come a long way, and these features certainly have made it more enjoyable.

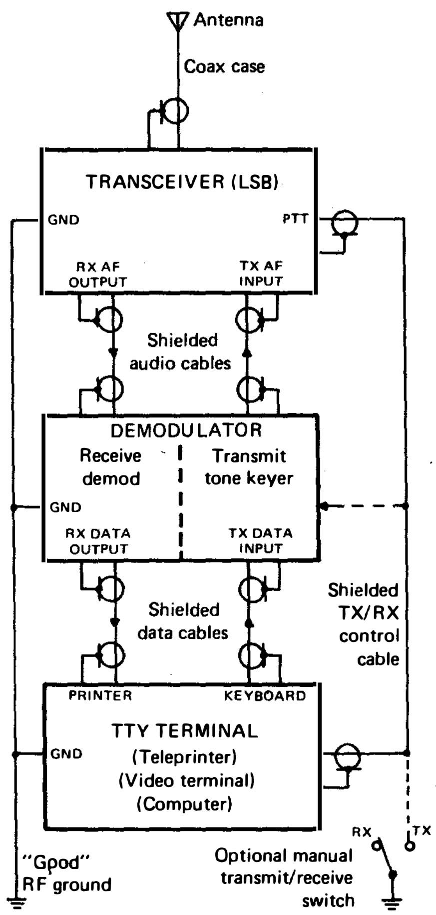

Fig. 1– Typical RTTY station.

One part of the RTTY station that has not necessarily improved is the demodulator section, sometimes called the **Terminal Unit,** or **TU.** As the revolution in electronics was applied to improved electronic replacements for the old keyboard and printers, it became more and more attractive to put the entire RTTY system in just one cabinet and eliminate all those messy and confusing wires. Also, it was noticed that solid state terminals really don't need the big, heavy loop power supplies and motor control relays. So, the RTTY demodulator was simplified, combined with the video terminal circuitry, and put in one attractive cabinet. With this new equipment, the only cables you need to work RTTY are a few simple ones to hook to the transceiver.

Unfortunately, in the rush to miniaturize and simplify the demodulator, we lost some very important demodulator features and performance. Some of the one-package units have continued to include a high-performance demodulator. However, other units include only the most basic circuit for RTTY demodulation. The RTTY beginner is the one who suffers the most from this problem; he has never operated RTTY before. He therefore must assume that RTTY only works with no QRM and on signals that are S9 or stronger, or that the speaker volume must be turned up to just short of the threshold of pain. These handicaps are just not true, and we proved it 10 to 20 years ago! If your RTTY system suffers from bad print in QRM and you can't tune your transceiver to the other guy's signal, *read on!*

The RTTY demodulator is part of our receiver. It takes the tones from the receiver, separates them from the noise and interference, and then reconstructs the digital signal to drive our printer or video screen. I am sure we have all heard the old saying about receivers: "If you can't hear 'em, you can't work 'em." This is even more true of RTTY. Just like the old timers used to advise us beginners to "put our money in a receiver," the newcomer to RTTY will get more benefit from a good demodulator than from any other section of the RTTY station. This is particularly important when operating on the h.f. bands (80–10 meters).

Single-Tone Demodulators

We transmit RTTY on h.f. using **FSK** (**F**requency **S**hift **K**eying) to send out one of two radio frequencies: one for the MARK pulse condition, and the other for the SPACE condition. To take *full* advantage of the signal we receive, we should be capable of detecting *both* signals and using *all* of the information transmitted. However, there are, in fact, many circuits that only include the capability for reception of just one of the two tones, usually the SPACE tone. This circuit uses a simple one-tone filter and detector and works well on v.h.f.-f.m. or when the h.f. signals are 20 over 9 and there is no QRM. They do fall apart, though, when signals fade or when QRM is present. The circuit is, however, very simple and takes only a few parts to build; for a manufacturer, it is very cheap. You also do not get an output for a good tuning indicator, so it can be next to impossible to accurately set your transceiver to the other guy's frequency. This causes the "frequency-walking" we have all observed as each station in turn "tweaks" the frequency on each transmission.

Phase-Locked-Loop Demodulators

Another simple circuit that has gained a lot of popularity is the phase-lock-loop **(PLL)** demodulator. Because the entire circuit is contained in one or two integrated circuits, this circuit is also quite simple and low cost. It also works considerably better than the single-tone, SPACE-only demodulator.

The PLL demodulator works by using a *phase detector* and *voltage-controlled oscillator* **(VCO)** in a feed-back circuit. The feedback connection is arranged so that the difference in frequency between the received audio signal and the VCO produces a d.c. voltage which then adjusts the VCO to be nearly the same frequency as that received. The d.c. voltage therefore will vary somewhat as the input audio frequency changes between MARK and SPACE conditions. This voltage is then filtered and amplified to produce the required MARK and SPACE pulses to drive the printer or video terminal.

Phase-lock loops, however, have a very nasty characteristic that makes for less than ideal RTTY detection. Phase-lock loops, by nature, will lock on *any* signal that is within their "lock-range." Moreover, they will lock on the *strongest* signal in this range. If your desired RTTY signal is, in fact, the strongest signal in the PLL's lock range, you will get excellent copy of the received signal. However, if the RTTY signal fades or a strong signal (such as c.w.) comes on anywhere near the RTTY signal, the PLL very happily locks onto it, ignoring the RTTY signal. Often, many RTTY characters are lost while the PLL either tracks interference or attempts to switch back and forth between an RTTY signal and an interfering c.w. signal. Phase-lock loops do, of course, work very well on v.h.f.-f.m. RTTY where there are no interfering signals. They leave a lot to be desired when used on our crowded h.f. bands. The PLL also has *no* tuning indicator output, and this leads to the same problems discussed above in regard to the single-tone demodulator.

High-Performance Demodulators

There are, however, two similar, but

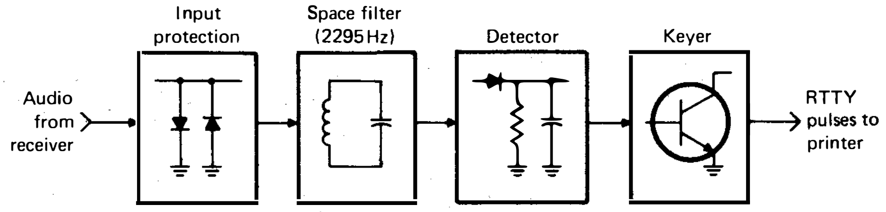

Fig. 2– Typical single-tone demodulator.

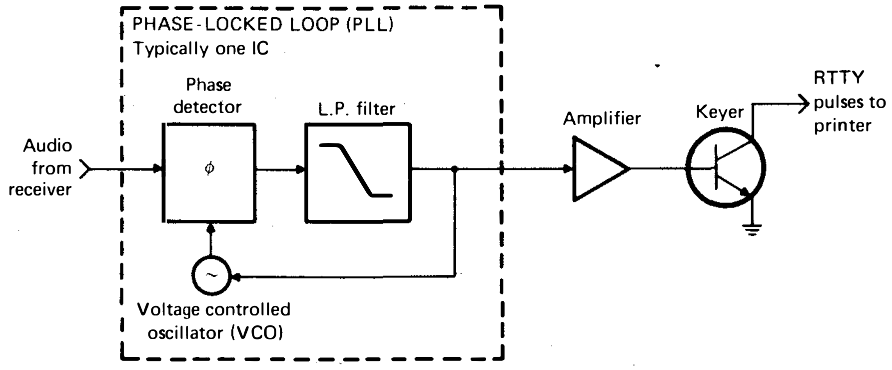

Fig. 3– Typical phase-locked-loop demodulator.

different demodulator systems that give superior performance in detecting and demodulating RTTY signals. These two are: (1) the **FM** or *"hard-limiting"* demodulator and (2) the **AM** or *non-limiting"* demodulator. The two circuits are similar in that they both include the basic requirement of *separate* filters and detection circuits for both the MARK and SPACE pulses. Both types of demodulators also generally will include a good post-detection filter followed by a high-gain slicer (circuits often omitted from the simple one-tone and PLL demodulators). Both demodulators have outputs that may be used for very accurate tuning of the RTTY signal.

F.M. (Hard-limiting) Demodulators

The f.m. demodulator works on the principle that the received RTTY information is contained only in the frequency variation between MARK and SPACE tones; RTTY is an f.m. mode. Therefore, the f.m. demodulator circuitry will closely resemble that used in an f.m. receiver. In an f.m. demodulator, the RTTY audio tone signals from the receiver are first passed through a very high-gain amplifier so that all amplitude variations in the signals are removed. The constant amplitude, square-wave type of signal is then processed in a discriminator, producing opposite polarities for MARK and SPACE tone frequencies. In practice, f.m. RTTY demodulators rarely try to achieve the straight-line discriminator response we want in an f.m. receiver. Rather, since we know what frequencies the MARK and SPACE tones should be, sharply tuned filters are used in separate MARK and SPACE detectors. However, great care must be taken to assure that these filters are wide enough to pass all of the RTTY information and that both filters have the same bandwidth so that noise in both of them will then cancel when the two detector outputs are summed. The f.m. demodulator works very well and will often give perfect copy on very weak signals you can hardly hear.

The f.m. mode does, however, have one inherent weakness. Just as your f.m. receiver limiter stage will be "captured" by the strongest signal within its passband, so can the limiter stage of an f.m. RTTY demodulator. This disadvantage is, however, greatly reduced when band-pass filter circuits precede the limiter stage. Some f.m. demodulators include such audio filters; others work much better if you use the c.w. filter in the receiver itself. When such filters are used, the "capture" effect is rarely a serious problem. Moreover, the f.m. demodulator tends to be simple to use with few adjustments, is not amplitude sensitive, and will give good results on a very weak audio signal. F.m. demodulators do produce an excellent tuning indicator output.

A.M. (Non-Limiting) Demodulators

The a.m., or non-limiting, demodulator also uses sharply tuned filters before the MARK and SPACE detectors and usually employs a good post-detection filter and slicer stage. However, the amplitude of the input audio signal is not limited, and special circuits, often using a.g.c. and d.c. level restoration, are required to balance amplitude variations between the MARK and SPACE receive tones. The a.m. demodulator can be designed to perform every bit as well as the f.m. system. It also does not have the problem of limiter "capture" on strong signals. The a.m. circuit does, however, tend to be much more critical as to the amplitude of the received tone. This usually means that the receiver audio gain must be set louder for good copy and that the oper-

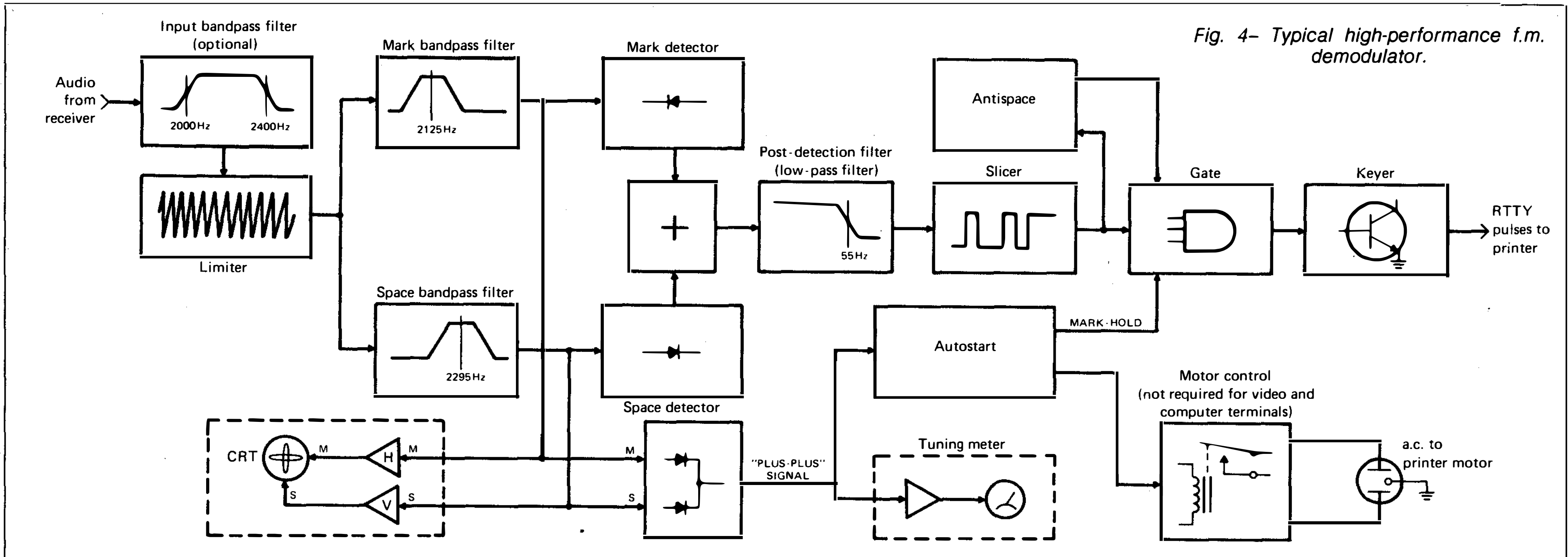

Fig. 4– Typical high-performance f.m. demodulator.

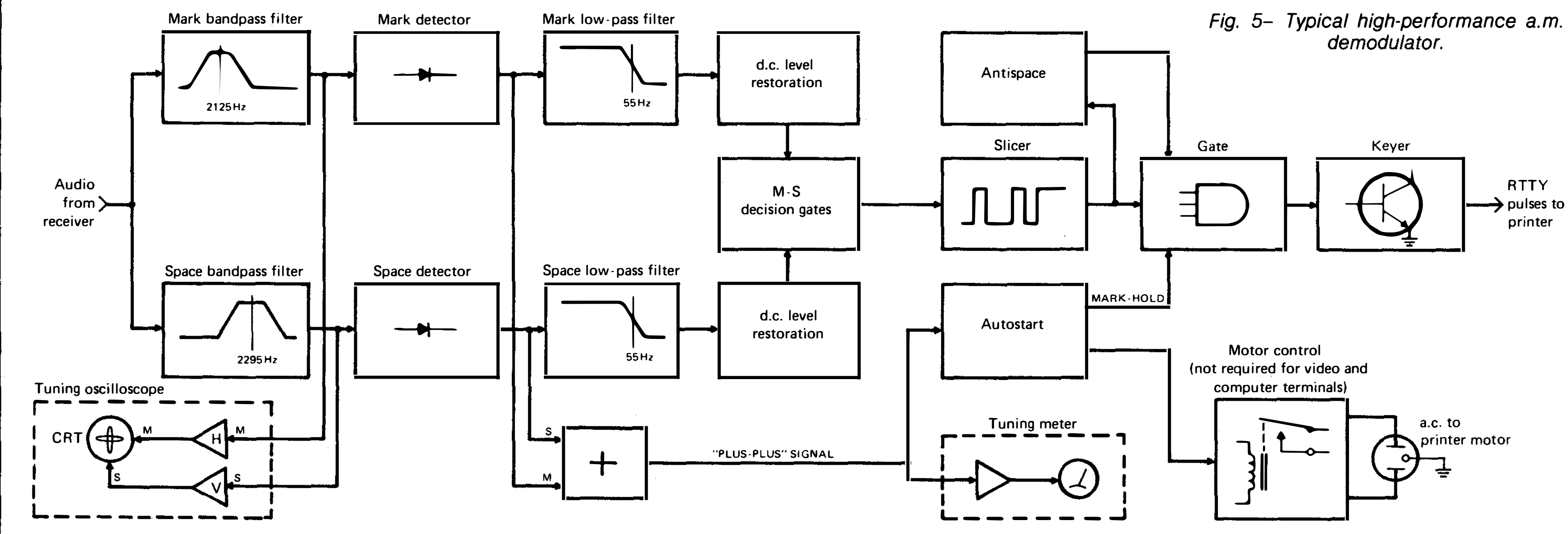

Fig. 5– Typical high-performance a.m. demodulator.

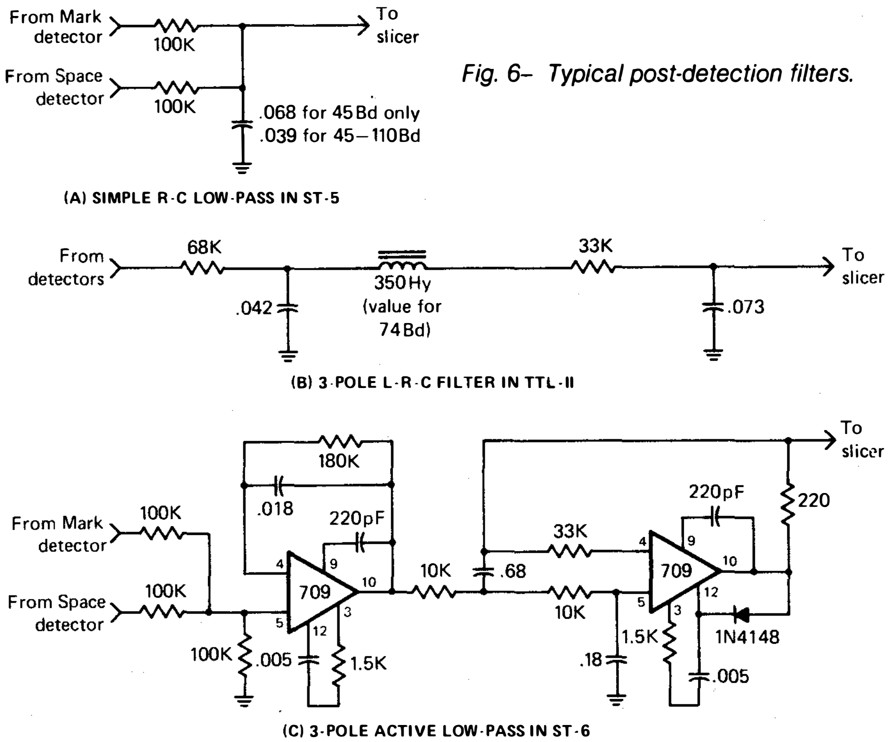

Fig. 6– Typical post-detection filters.

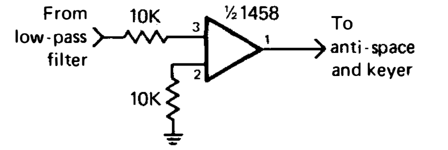

Fig. 7– Slicer stage in ST-6000.

ator must keep close track of the audio level to prevent overloading the input stages with too strong an input. In practice, modern receivers have good, wide dynamic-range a.g.c. systems that take much of the adjustment burden off the operator. However, the a.m. system will rarely give good copy of a signal that has faded below the a.g.c. adjustment range of the receiver, a situation at which the f.m. system excels. The a.m. demodulator also has an excellent tuning indicator output.

As to "which is better—a.m. or f.m.?" there can be no hard and fast answer. High-performance demodulators using a.m. and f.m. techniques can be connected to the same receiver, and the results certainly will be different with one unit giving better print in some conditions and the other unit giving better print in other conditions.

Post-Detection Filter

Finally, when considering good demodulator circuits, don't just stop at the detector stages. The stage following the detector is often said to be the most important of all in the demodulator. This stage is the **post-detection filter,** often called simply the **low-pass filter stage.** The output signal from the MARK and SPACE detectors includes *all* signal components that pass through these stages. However, because we know the speed or rate at which the RTTY signal is transmitted, we know the bandwidth of our desired signal. The bandwidth of the RTTY pulse signal is approximately one half the baud rate of that signal. Therefore, a 45 baud (60 w.p.m.) pulse signal has a bandwidth of only 22.5 Hz. We can eliminate much of the noise from the detectors by using a filter that is tailored to the bandwidth of the expected signal. For 45 baud reception, 25 Hz is often used as the post-detection low-pass cut-off frequency. However, if the filter is set to this narrow value, *only* 45 baud (60 w.p.m.) signals may be received. The bandwidth should be 29 Hz for 57 baud, 37 Hz for 74 baud, and 55 Hz for 110 baud signals. The TTL and TTL-II demodulators were, in fact, built with switchable low-pass filters for different speeds for this reason. However, amateur operation showed little gain in performance when optimized filters were used, and most demodulators now are built using a compromise bandwidth of 50–60 Hz so that all data rates between 45 and 110 baud may be received without changing filters. However, this "rule" can be stretched only so far, as has been proven when amateurs increased the low-pass bandwidth to 150 Hz to accommodate 300 baud signals. Not only did 300 baud not work very well on h.f., but 45 baud performance was also noticeably worse.

Slicer Stage

After the pulse signal has been bandwidth-limited in the post-detection filter, the pulses will have very rounded rise and fall times when viewed on an oscilloscope. While this signal does contain all of the information to be received, the rounded pulses will not be treated kindly by a teleprinter's selector magnets or by the input UART (**U**niversal **A**synchronous **R**eceiver Transmitter) of the video terminal. Therefore, a high-gain wide-bandwidth "slicer" stage is used after the low-pass filter to regain the clean, square-edged pulses we need. This stage is also

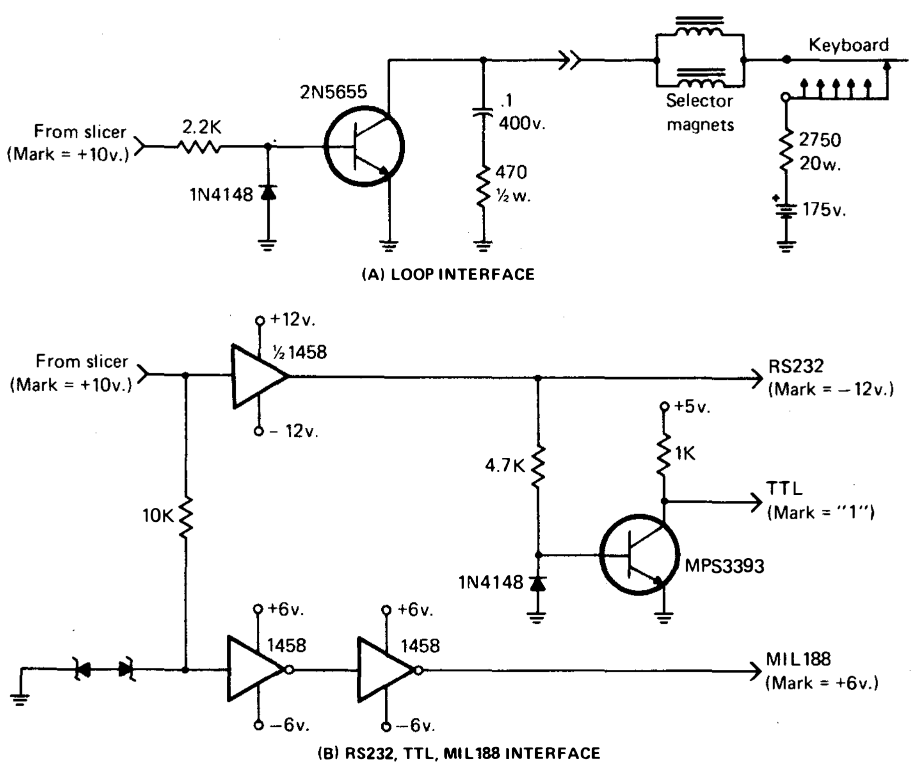

Fig. 8– I/O interfaces.

critical. It must give absolutely "equal treatment" to both the MARK and SPACE signal polarities or distortion will be introduced and the print may be garbled.

Level Correction Circuits

Often, a special circuit is used with the "slicer" to assure pulse symmetry, even when one or the other tone fades in selective fading. Such circuits are often called **DTC D**ecision **T**hreshold **C**ontrol) or **ATC** (**A**utomatic **T**hreshold **C**ontrol). These circuits will provide compensation and d.c. level restoration for fading signals, but they may also contribute a noticeable amount of distortion of their own if the signal is not sent at the expected data rate. Such a case occurs with ATC when receiving hand-typed text; turn ATC off in this case!

Output Interface Circuits

After the slicer, the RTTY signal is a clean pulse, and it only remains to change the polarity and/or level so that it is compatible with the teleprinter or video terminal. Most amateur teleprinters use a high-voltage series current-loop circuit. A high-voltage transistor generally is used to switch the current on and off **(ON= MARK).** Video terminals usually require an RS232C voltage data input. In this case, special line driver IC's are used to give the required output (– V = MARK, + V = SPACE; – 25 < V < + 25). Computers, used as terminals, may use either RS232C or TTL data inputs (TTL MARK = "1" > 3.5V; SPACE = "0" < 1.5V). Some demodulators also include an MIL188 output for connection to military equipment (MARK = + 6V; SPACE = – 6V). Which of these outputs are included in a demodulator varies from unit to unit and manufacturer to manufacturer.

Conclusions

In summary, consider that the RTTY demodulator is the single most important section of your RTTY station. The simple single-tone and PLL demodulators will receive RTTY signals. But, much improved reception will be available if a high-performance demodulator is used. The difference is often astounding. High-performance demodulators come in two basic forms: f.m. and a.m. Both systems have their advantages and drawbacks, and both systems can work extremely well. Unfortunately, the better the performance of the demodulator, the more complicated its circuitry and the higher its cost. This is probably still another example of "you get what you pay for."

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