First, set the audio source to the desired tone frequency by the tuning-fork, tape-recorder or decade-box method. Then tune each section in Fig. 7 independently to that same audio tone. In Fig. 7A do not change or remove C_{AB} but instead add to the value of C_A until the meter peaks, showing that the desired frequency has been reached. (Turns may also be added to or removed from the coil, if more appropriate.) When this section has been tuned, remove capacitor C_{AB} and connect it in the second section as in Fig. 7B. Tune this section to the identical audio frequency by varying C_B or the turns on the inductor. Set aside, removing capacitor C_{BC}, which is then used to tune the third section as shown in Fig. 7C. When this section has been tuned to the same audio frequency put the filter together as in Fig. 6, making sure no (more) turns are removed from any of the toroids in the process. This completes the filter tuning.

Other methods of tuning the filters can be used – indeed, many different schemes are possible. Elaborate and expensive equipment is not required, although in some instances it might make the job a bit easier. It would appear that an audio tape recorder in conjunction with a capacitor decade box and vacuum-tube voltmeter would be an ideal method available to most individuals. Just the decade box with a VTVM and a reasonably stable audio oscillator probably would work just as well.

THE MAINLINE TT/L-2 FSK DEMODULATOR

The demodulator described in this section is an advanced-design unit which was originally described by Petersen, W8SDZ, in *QST* for May and June, 1969. It offers high-performance fm (limiter) and a-m (limiterless) reception of RTTY signals. The earlier TT/L demodulator, as published by Hoff in *QST* for August, 1965, was the result of almost two years' work. Because of the desire to make each part of the basic design as nearly perfect as possible, the circuitry went through continuous improvements after that information was published. Nearly four years later, when it was felt by Hoff and Petersen that all circuits had been fully optimized, the TT/L-2 appeared in print.

The TT/L-2 demodulator includes band-pass filters for both 850- and 170-Hz shift. It also includes a three-speed switch for the low-pass filter stage following the discriminator detectors. This feature selects the optimum cutoff frequency for each transmission speed, 60, 75, or 100 wpm. With the increasing availability of equipment which will operate at the higher speeds, this feature is especially timely.

An effective auto-receive stage in the TT/L-2 prevents the receiving teleprinter from printing garble when there is no RTTY signal present, and completely ignores cw and other non-RTTY signals which may be within the received passband. The auto-receive circuit also controls a motor-control stage which turns off the teleprinter motor approximately 30 seconds after the signal leaves. (This delay is sufficient to keep the motor running during station identification and subsequent "turnover" to another station.) The combination of the auto-receive and motor-control stages provides an efficient and reliable system for obtaining unattended reception of RTTY signals.

The TT/L-2 includes protection against a steady space tone, which would otherwise cause the teleprinter to "run open." This circuit also prevents the auto-receive circuit from responding to steady space signals.

The TT/L-2 incorporates a simplified mode-switching system, using a single six-position rotary switch. This feature eliminates much of the confusion which could result from using many separate switches. The switch controls four different functions, interlocking them so there is no possibility of a wrong combination which might cause improper operation.

Heavy-duty main and loop power supplies are used for cool operation and good regulation.

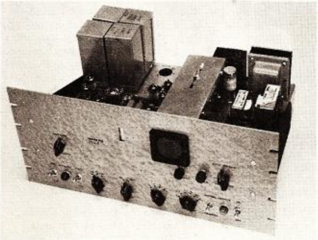


Fig. 1 – The TT/L-2 demodulator built for rack mounting. This unit, constructed by John Roache, W1SOG, includes a phase shift oscillograph indicator in addition to the eye-tube indicator described in the text. The main and loop power supply components are mounted on the right rear of the chassis. Plugged into sockets at the left rear are the two Butterworth input band-pass filters and the two discriminator filters, each built into a Minibox fitted with an octal plug. One of four vacant sockets may be seen at the rear of the unit. These sockets are used in conjuction with the spare positions of the discriminator filter section switch.

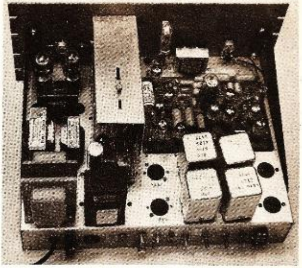


Fig. 2 — A look at the TT/L-2 from the rear. Suggested chassis size is 13 X 17 X 3 inches, such as a Bud AC-420. The K5BQA printed circuit board was used in the construction of this unit. The two tubes appearing on the upper left corner of the chassis are the voltage regulator tubes of the power supply. The eye-tube indicator is mounted at the opening in the front panel. Input band-pass and discriminator filters are built into Vector, cans and inserted in the filter sockets.

This is especially important when the unit is used for continuous auto-start operation. The loop supply provides a balanced-voltage output for driving a saturated diode for fsk or afsk operation. The circuit also permits automatic retransmission of received signals — such as for relaying from another band or playing back from a tape-recorded signal.

The EM84/6FG6 tuning eye is used because it is a more accurate indicator than either an oscilloscope or a meter. It shows at a glance when the signal has drifted, and is especially effective when "straddle-tuning" is necessary due to inaccurate shift by the sending station.

You will notice that no power-on indicator has been included in this design. It was purposely omitted because the tuning eye provides this indication. The TT/L-2 is pictured in Figs. 1 and 2, with an optional scope tuning indicator included.

The Circuit

The circuitry of the TT/L-2 Demodulator is shown in Fig. 3. Fig. 4 shows the schematic of the power supplies and the fsk driver.

Two input-bandpass filters are provided, one for 850-Hz and the other for 170-Hz shift. Selection of the desired filter is made with S1. V2 and V3, the limiter stages, are used for fm reception. These stages may be bypassed for limiterless reception with S2.

A four-position switch, S3, is shown in the discriminator filter section for selection of filters with different responses. Only two filters are included in this design, as it was felt that the builder might wish to add other filters at a later date, after becoming better acquainted with the operation of the TT/L-2. The narrow-band 3-pole Butterworth filters described in the preceding section on high-performance RTTY filters could be installed in the extra switch positions.

The speed switch, S5, is used to select the components for 60-, 75-, or 100-wpm signals. This switch is shown in the 60-wpm position, and may be omitted if you have no interest in 75- or 100-wpm operation. In this case, only the parts associated with the left position of the switch are required.

Special Notes

All diodes except those in the power supplies and the Zener in the auto-receive stage are type 1N2070A. It is important, especially in the ATC/DTC stage, that the diodes have at least 200 megohms back resistance.

All controls are linear taper. Those marked 2 watts are Ohmite type AB or equivalent.

Capacitor values shown with asterisks in the input band-pass filters are approximate. Using the tune-up instructions presented in the "High-Performance RTTY Filters" section, tune individual sections of the 170-Hz filter to 2200 Hz. The 850-Hz filter requires no tuning if 5% tolerance capacitors are used. Otherwise, tune filter sections A and C to 2400 Hz, and section B to 2300 Hz. Figs. 6 and 7 of the preceding section of this chapter show these filter sections.

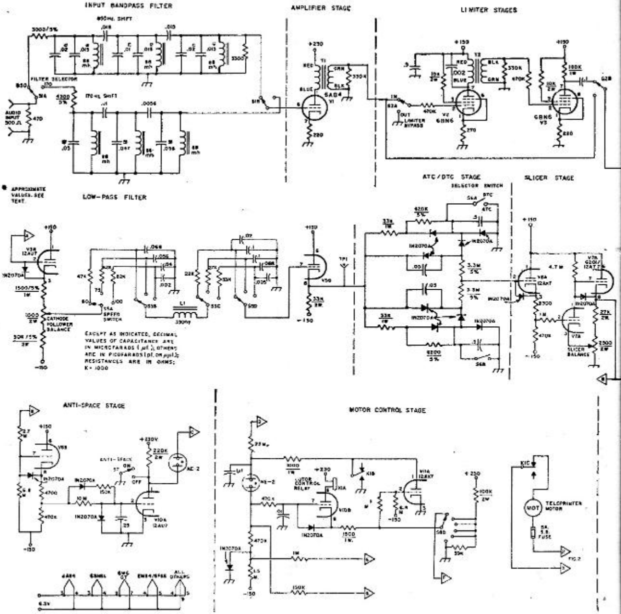
Capacitor values in the discriminator filters are approximate. Choose values for resonance with the appropriate toroid at the desired frequency.

Construction Notes

The layout used for construction of the TT/L-2 should be similar to that used in a high-quality audio pre-amplifier. This type of layout is desirable because of the very high-gain circuitry used. Be sure to shield all audio and high-impedance dc leads which might otherwise pick up extraneous signals or noise because of physical length or placement.

The wiring associated with the grids of V1, V5A, V6A and V11B should either be very short or else be shielded.

It is most important that T1 and T2 be mounted in such a way that they will not pick up inductively from each other, from T3 and T4, or from the power supply transformers and chokes. The best method is to mount each of the four transformers on different axes. Do not mount one above and one below the chassis in an effort to avoid inductive coupling, because the usual aluminum chassis used will not provide inductive shielding. Also be sure the 350-H choke in the low-pass filter section is not mounted near any of the power supply transformers or chokes.



The 5-volt ac winding of the main power transformer, T6, is not used, and the leads should be insulated and secured to prevent their shorting out. This winding is a spare, for possible future use. Particular attention should be paid to the indicated connection of the secondary of transformer T2 for proper phasing to avoid feedback.

Shield all leads associated with the limiter bypass switch, S2. The 0.47-megohm series grid resistors for V2 and V3 should be located right at the grid pin for each tube socket. All switches except S7 should be mounted on the *front* panel. S7, the anti-space ON-OFF switch, is used for test purposes only, and may therefore be mounted on the rear panel since it is not used in normal operation.

The test point located at the cathode follower output of the low-pass filter should be mounted in a convenient spot on or near the rear panel.

The auto-receive sensitivity control and the indicator sensitivity control should be mounted on the *front* panel. All other potentiometers should be mounted on the rear panel.

The RECEIVE and STANDBY neon indicators may be mounted on the front panel, if desired, to show when the unit is ready to receive a signal. Be sure the sockets do not contain any resistors. If the builder does not wish to include these indicators for front panel use, the RECEIVE STANDBY neon must be retained, however, as it is used as a coupling device. Many neons (about 20%) are not good performers due to manufacturing tolerances,

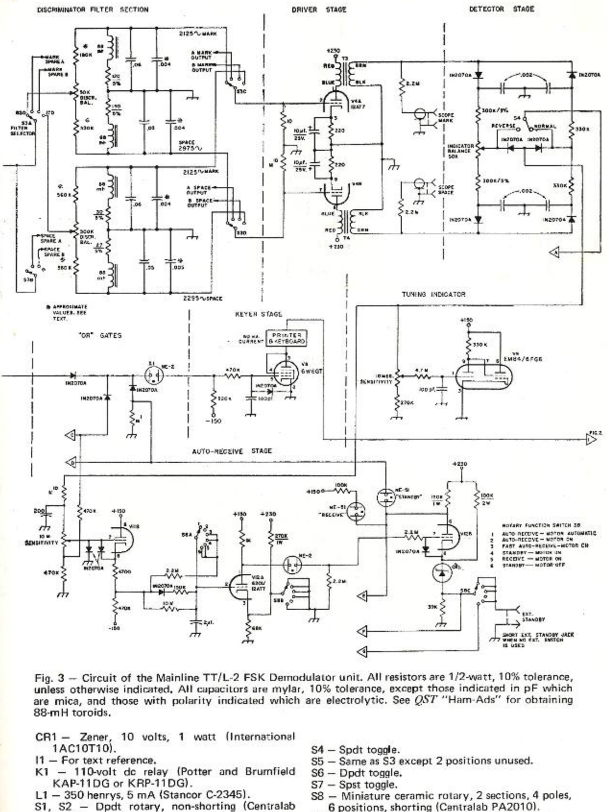


Fig. 3 — Circuit of the Mainline TT/L-2 FSK Demodulator unit. All resistors are 1/2-watt, 10% tolerance, unless otherwise indicated. All capacitors are mylar, 10% tolerance, except those indicated in pF which are mica, and those with polarity indicated which are electrolytic. See *QST* "Ham-Ads" for obtaining 88-mH toroids.

CR1 — Zener, 10 volts, 1 watt (International 1AC10T10).
I1 — For text reference.
K1 — 110-volt dc relay (Potter and Brumfield KAP-11DG or KRP-11DG).
L1 — 350 henrys, 5 mA (Stancor C-2345).
S1, S2 — Dpdt rotary, non-shorting (Centralab 1464).
S3 — Miniature phenolic rotary, 2 sections, 4 poles, 5 positions (1 position unused), non-shorting (Centralab PA1013).
S4 — Spdt toggle.
S5 — Same as S3 except 2 positions unused.
S6 — Dpdt toggle.
S7 — Spst toggle.
S8 — Miniature ceramic rotary, 2 sections, 4 poles, 6 positions, shorting (Centralab PA2010).
T1, T2, T3, T4 — Interstage audio, 1:3 primary: secondary turns ratio; 10 mA (Stancor A-53).

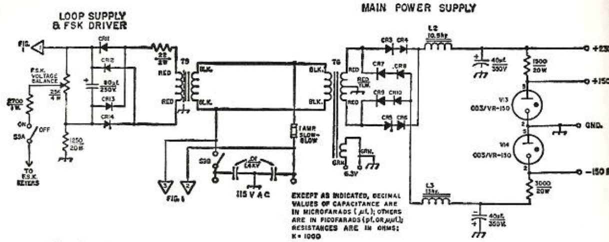


Fig. 4 — Power supplies and fsk driver for the TT/L-2 Demodulator.
CR3-CR14 incl. — Silicon, 800 PIV, 500 mA (Sarkes-Tarzian F-8).
L2 — 10.5 H, 110 mA (Stancor C-1001).
L3 — 13 H, 65 mA (Stancor C-1708).
S9 — Dpst toggle, 15 A, 125 volts.
T5 — 115 V, 35 VA (Triad N-51X).
T6 — 550 V ct, 110 mA; 6.3 V, 5 A; 5 V, 2 A (Triad R-12A).

so an extra few should be purchased. If any trouble is experienced with either the auto-receive or the motor-control stages, the builder should try another neon.

ADJUSTMENT INSTRUCTIONS

Allow the unit to warm up for at least fifteen minutes before any adjustments are made. The tubes will age during the first few days of operation, so it is wise to repeat the entire adjustment procedure approximately a week after inital setup has been performed. These adjustments should always be done in the order shown below, or improper operation will result.

Cathode-Follower Balance

The first adjustment to be made is the cathode follower balance control in the low-pass filter stage. Connect a senstive VOM or a VTVM to the test point, TP1. Remove the audio input from the TT/L-2 by unplugging the input cable. Set the limiter bypass switch to the OUT position. Adjust the cathode follower balance control for zero volts dc at the test point. If it is not possible to reach zero, and a new tube has already been tried, change the value of the 1500-ohm resistor in the cathode circuit of V5A as necessary so the adjustment can be made properly.

Slicer Balance

The slicer balance adjustment is also made with no audio input and with the limiter bypassed. The anti-space switch, S7, should be set to the OFF position and the rotary function switch, S8, should be set to position No. 5 (RECEIVE — MOTOR ON) for this adjustment. Turn the slicer balance control until the teleprinter "runs open." Then turn the control in the opposite direction until the printer returns to the marking condition. Note these two points, and set the control midway between. No further adjustment is necessary.

Return the anti-space switch to the ON position.

Discriminator Filter Section

The discriminator filters should be tuned to resonance for the desired tone frequencies by varying the capacitors marked with asterisks. When adjusting the filters for resonance, the resistors in series with the ground connection of the toroids should be shorted out temporarily. Be sure to remove these shorts after the tuning is completed, or severe distortion of the received teleprinter signals will result. For additional tuning hints, refer to the section on high-performance RTTY filters.

The resistors marked with asterisks on either side of the balance controls should be chosen for each filter so that the dc voltages developed from mark and space tones, when balanced, do not exceed ±60 volts at Test Point 1. If adjustment is required, change both resistors by an equal amount, so as to maintain a balance within the range of the control.

Adjustment of each discriminator balance control is made with the limiter bypass switch set to the IN position, and the normal-reverse switch, S4, set in the NORMAL position. Alternately apply a mark and space tone to the input of the TT/L-2. Adjust the discriminator balance control so that the mark and space dc voltages are equal, but of opposite polarity, at the test point.

Indicator Balance

After the discriminators have been balanced, set the normal-reverse switch in the REVERSE position. Now adjust the indicator balance control for equal mark and space dc voltages at the test point. Observe the tuning eye. Carefully adjust the indicator balance control to eliminate any eye

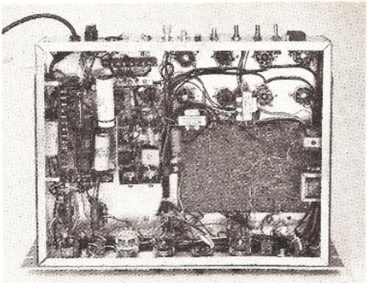


Fig. 5 — The inside of the TT/L-2. Components at the left are those of the power supplies. The concentration of parts inside the partially shielded compartment is associated with the phase-shift indicator circuitry. Most small components are mounted on the opposite side of the printed circuit board.

movement when alternating between mark and space tones. No further adjustment is necessary.

FSK Voltage Balance

Set the rotary function switch, S8, to position 4 (STANDBY — MOTOR ON). Connect a test voltmeter from the FSK DRIVER output to ground. Disconnect the external fsk keyer lead during this adjustment. Alternately open and close the printer loop by pushing the "break" key or opening the keyboard contacts at the teleprinter. Adjust the fsk voltage balance control for equal but opposite mark and space dc voltages. The mark voltage should be approximately −45 volts and the space voltage should be approximately +45 volts. No further adjustment is necessary.

CORRECT VOLTAGE CHECKS

With a 1.5-volt peak-to-peak 2125-Hz tone at the grid of V1 and the limiter switched in, there should be approximately 40 volts peak-to-peak at the plate of V1, 10 volts peak-to-peak at the grid of V2, 45 volts peak-to-peak at the grid of V3, 40 volts peak-to-peak at the center of the discriminator balance control, and 40 volts peak-to-peak at the plate of V4A. There should be about 120 volts at the secondary of T3.

Dc voltages are present from this point on. The grid of V6A should be approximately −50 volts with the ATC/DTC switch at DTC, and about −28 volts at ATC. All of the following voltages should appear with the switch at DTC. The cathode of V6A should be about −50 volts, the grid of V7A −45 volts, and the grid of V8 between 0 and −0.2 volt. With a space tone at the input and with the anti-space switch turned off, the grid of V8 should be about −50 volts. The junction of neon I1 and the two resistors in the keyer stage should be at +10 to +20 volts with a mark-tone input.

OPERATION

The proper audio input level for the TT/L-2 is that which produces the same amount of tuning-

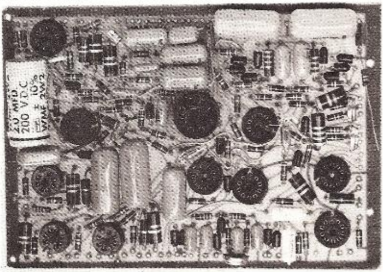


Fig. 6 — A close-up of the K5BQA printed board with all components mounted. Measuring approximately 6 X 9 inches, the board contains tubes and components of the amplifier, limiter, driver, detector, low-pass filter, ATC/DTC, OR gate, keyer, anti-space, motor-control, and auto-receive stages. (Jim Salter, K5BQA, 11040 Creekmere, Dallas, TX 75218.)

eye closure in either the fm (limiter) or a-m (limiterless) mode of operation. You will find that this is slightly above normal room volume, and it will be necessary to install a pad in the speaker circuit to bring its volume down to a suitable listening level. The pad also offers the advantage of decoupling the variable impedance of the speaker from the receiver output circuit.

It is best to use your receiver's 100-kHz crystal calibrator or an actual signal to make the auto-receive sensitivity adjustment. Set the rotary function switch to position 2 (AUTO-RECEIVE – MOTOR ON). With no signal (just noise) input to the TT/L-2, adjust the auto-receive sensitivity control to a point just below that where the teleprinter prints garble. The printer should now remain quiet. Now adjust the sensitivity control so that when a signal is applied there is a 3- to 4-second delay before the RECEIVE neon indicator lights. If your adjustment is correct, the teleprinter should print five or six letters after the signal leaves, and then remain quiet.

The auto-receive circuit was designed to be used only when receiving in the fm (limiter) mode. When the a-m (limiterless) mode is used, the rotary function switch, S8, should always be placed in the No. 5 position (RECEIVE – MOTOR ON). The motor-control stage works only when the auto-receive circuit is in operation.

The tuning-indicator sensitivity control is provided so that the user may control the amount of eye closure during operation. The best setting is one where the eye just closes with the signal tuned properly. If the signal drifts, the eye immediately starts to open, signaling the operator to retune.

S6 is used to select the Automatic Threshold Corrector or the Decision Threshold Computer. The DTC is used at all times except for reception of mark-only or space-only signals.

During transmission, the EXT. STANDBY switch must be opened, so that the signal will not feed back into the loop. When retransmitting or transmitting from tape-recorded signals, the switch must remain closed.

THE MAINLINE ST-4 RTTY DEMODULATOR

What are the minimum RTTY demodulator requirements for reception of both vhf and hf? When receiving RTTY signals on vhf, many of the problems associated with the hf bands just do not occur. Such things as selective fading, adjacent-channel QRM, static due to thunderstorms, and so forth, are rarely encountered. In addition, fm is often used together with repeaters, where fluctuations in signal strength are not a problem. Squelch is normally available to lock the receiver into standby if there is no signal present. Cw interference is rarely encountered, and so few stations are present that crystal operation is frequently used, keeping adjacent-channel interference to a minimum.

As a consequence, the most elementary TU or demodulator is often quite enough, and many of the unique problems of the hf bands are of no concern to the vhf enthusiast. The schematic of the typical vhf RTTY TU amply demonstrates the simplicity possible. On the other hand, almost none of the units designed for vhf are really much more than barely adequate when used in the hf bands.

At hf we get into problems which are rarely experienced on higher frequencies. Probably the worst problem of all is cw interference, and next is adjacent-channel interference (other stations close by). Static, high noise levels, selective fading, improper shift, and drift all contribute to the "nightmare" of hf RTTY. To minimize cw interference (probably the toughest of all the problems), you can turn the receiver avc off and go to limiterless copy with sharp filters. This takes a rather advanced demodulator design, such as the Mainline TT/L-2* with the sophisticated threshold computer and narrow Butterworth filters.* This is also the answer for selective fading and adjacent-channel interference. Not much can be done to eliminate static and high-noise-level problems.

What *are* the minimum requirements for both vhf and hf? This is a somewhat difficult question to answer because it depends so much upon your own experience. First of all, you need a good limiter. (Let's omit "limiterless" demodulators from the minimum-requirements discussion.) Few demodulators have offered a really decent limiter in the past, other than the TT/L or TT/L-2, which limit to around −60 dB. (Zero dB is defined as 0.774 volt across a 600-ohm load, a condition producing 1 mW of power in the load. However, the dB reference here is made to the voltage level rather than the power level, because the impedance throughout the circuit is not necessarily 600 ohms. The −60 dB refers to the minimum input signal level at which the sine wave starts becoming limited.)

You will also need well balanced filters to develop similar voltages for both mark and space tones, and to obtain good noise cancellation when there is no signal. You should have a high-voltage loop supply of at least 120 volts and preferably more, 150 to 250 volts. Although the RTTY machine itself can work on voltages as low as 24 volts and even less, immense amounts of distortion are added. It has been shown that printers operated in a 12-volt loop can easily exceed 60 percent spacing bias. This amount is essentially intolerable. Raising the loop potential to 36 volts can still result in as much as 30 to 33 percent spacing bias. If the incoming signal is also distorted, this can create an immense number of printing errors at times when others may copy perfectly. With a 150-volt loop, the bias can be reduced to 2 percent or less, an insignificant amount.

*See preceding sections.