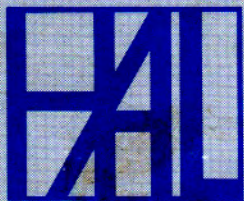# AK–1

AFSK OSCILLATOR

INSTRUCTION
MANUAL

HAL COMMUNICATIONS CORP.
BOX 365
URBANA, ILLINOIS   61801

QUALITY COMMUNICATIONS EQUIPMENT

AK-1

AFSK OSCILLATOR

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WARRANTY

HAL Communications Corp. warrants that the HAL Communications
Corp. factory-wired AK-1 AFSK Oscillator shall be free of
defects in materials and workmanship under normal use and
service for a period of one year. Should such defects occur
within the warranty period, notify HAL Communications Corp.
promptly. The warranty period is measured from the date of
the original invoice to the postmark-date of your notification
letter. Do not return your unit to the factory for repair or
adjustment until you have received written return authorization.

In the case of AK-1 AFSK Oscillator Kits, this warranty applies
only to the parts supplied in the kit and does not apply to
any wiring or components which, in the judgement of HAL
Communications Corp., were damaged by incorrect use or
construction on the part of the kit builder.

This warranty is and shall be in lieu of all other warranties,
whether expressed or implied, and of all other obligations or
liabilities on the part of HAL Communications Corp. resulting
from the installation or use of this oscillator.

The foregoing warranty is completely void on all AK-1's which
have been repaired by individuals other than HAL Communications
Corp. personnel, those which have been damaged, abused,
modified, improperly installed, or tampered with, and those
which have been subjected to improper voltages or currents.

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CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

The model AK-1 AFSK Oscillator is designed to generate tone-encoded teleprinter signals for transmission by either HF or VHF radio. Encoding is accomplished by shifting the frequency of the internal oscillator from its normal rest frequency ("mark" condition) to a higher frequency ("space" condition) as teleprinter keying pulses dictate. The rest or "mark" frequency output of the AK-1 is the standard 2125 Hz audio tone and the space frequency can be selected to be either 2295 Hz (170 Hz shift) or 2975 Hz (850 Hz shift). Additionally, the "mark" frequency can be shifted upward by approximately 100 Hz with a telegraph key to allow for CW identification of the radioteleprinter transmission.

The input keying requirements of the AK-1 are compatible with output signals from the HAL Communications ST-6 and ST-5 demodulators and can be easily keyed from other sources of low-voltage serial teleprinter data. Both high- and low-level audio outputs are available from the AK-1, providing a great deal of flexibility in interfacing the oscillator to various radio transmitter inputs. A five-pole Butterworth filter in the output stages of the AK-1 prevents generation of any spurious signals in the form of harmonics of the original audio tones.

The entire oscillator assembly is contained on one 2 7/8" X 5 3/4" circuit board, plugs into a 12 pin edge connector, and requires only a keying voltage and +12 volt power supply. The AK-1 circuit board is compatible with other circuit boards in the HAL ST-6 Demodulator and the AK-1 is a common option included in the factory-wired ST-6. The HAL AK-1 AFSK oscillator circuit is based upon a design described by Irvin Hoff, W6FFC, in the February, 1969 issue of QST magazine (page 11).

2. SPECIFICATIONS

Output Frequencies:

     Mark (170 and 850 Hz shifts) . . . . 2125 Hz
     Space (170 Hz shift) . . . . 2295 Hz
     Space (850 Hz shift) . . . . 2975 Hz
     CW ID (key down) . . . . 2225 Hz

Output Amplitude:

     High-Level Output . . . . 100 mV rms
     Low-Level Output . . . . 20 mV rms

Frequency Stability (after 15 minute warm-up) . . . . $\pm$ 5 Hz (all tones)

Standard Frequency Shifts available . . . . 170 and 850 Hz

Input Keying Voltage Requirements:

     Mark . . . . less than 0 volts, greater than -20 volts
     Space . . . . . . greater than +5 volts, less than +20 volts

Power Requirements . . . . +12 V dc @ 30ma

Size . . . . 2 7/8" X 5 3/4" circuit board
                                      (7.0 X 14.6 cm)

3. OPERATION OF THE AK-1

The circuit of the AK-1 AFSK Oscillator (see Figure 1, page 16) is made up of five basic sections: oscillator, keyer, divider, filter, and output amplifier. The signal is generated in a unijunction relaxation oscillator (Q4) at twice the desired output frequency. The exact mark frequency of oscillation is determined by the combination of C2 and R11, R12, and R13 (also Rc, if used). The frequency of oscillation is changed from mark to space condition by paralleling the R11, R12, R13 chain with either R6 and R7 (170 shift) or R4 and R6 (850 shift) series resistor chains. Therefore, shifting from mark to space frequencies is accomplished by changing the charging time-constant of capacitor C2, a procedure that generates no abrupt phase discontinuities in the oscillator waveform. This is a particularly important feature of the AK-1 when it is to be used in a SSB-type of transmitter system. For instance, oscillator circuits that use tuned-circuits will generate spurious signals due to phase discontinuities when shifting from mark to space. These spurious signals rarely cause problems in VHF-type AM or FM applications but will cause radiation of illegal signals when used with a SSB-type of transmitter. The AK-1 will not produce this type of spurious signal.

Changing the frequency from mark to space is accomplished electronically by keyer stages Q1 and Q2. Keying voltages are presented to pin 6 of the edge connector with the convention that for mark condition the voltage should be zero or less (preferably between -5 and -15 volts) and greater than +5 for space condition. Therefore, during mark, Q1 is "off" as is Q2 and the effective charging resistor for C2 is only the R11, R12, and R13 series chain. During space, both Q1 and Q2 are turned "on", paralleling either R4 and R5 or R6 and R7 (depending upon which is selected by S1) with the R11, etc. chain.

A separate keyer transistor, Q3, is provided for CW identification. When pin 7 of the edge connector is grounded, Q3 is biased "on" and R8 is placed in parallel with the R11, etc. chain, increasing the frequency by approximately 100 Hz. Note that this stage can be activated at any time and it is therefore important that the key (or its shorting-bar) not be closed during RTTY transmission. R8 has been chosen to give approximately 100 Hz shift from the mark tone, but the exact amount of CW ID shift can be adjusted by changing the value of this resistor.

It is important to note that both space tone and CW ID frequencies are determined by their respective resistor chains in parallel with the mark resistor-chain. Therefore, it is necessary that the mark frequency be adjusted first since any change in this resistor chain will affect all other tones. To allow compensation for the wide range of possible variation of the unijunction oscillator transistor, Q4, and timing capacitor C2, both a fine and coarse adjustment are provided for the mark frequency. The ranges of all potentiometers have been chosen so that it should always be possible to adjust to the correct frequencies without changing fixed resistors if the unit is constructed correctly.

3

The output of the oscillator across resistor R22 is a 2 volt spike at twice the desired output frequency. The divider stage (BSMV), Q5-Q6, is triggered by these pulses. The output of the divider (measured at the collector of Q6) should be a square-wave of approximately 10 volts peak-to-peak amplitude and with a frequency equal to the desired output frequency (2125 Hz for mark with key-up).

The low-pass filter removes all but the fundamental component of the square-wave, resulting in a sinusoidal output waveform. R24 is the input terminating resistor for the filter and R23 is a divider to reduce the voltage output and provide some isolation between the divider and filter. If desired, the output of the AK-1 can be increased somewhat by reducing the value of R23, but care should be taken to maintain the same parallel equivalent of R23 and R24 to keep the proper filter termination impedance. Since it is only necessary that the filter provide rejection of the harmonics of the divider output (odd-order harmonics for the square-wave), the filter does not require critical timing and can be assembled directly. If problems are suspected with the filter circuit, the pass-band can be checked by removing the end of resistor R23 from the collector of Q6 and substituting an audio oscillator, observing the output across C7. The filter should be "flat" (within 1.0 dB) up to 3000 Hz and should be of the order of 13 dB down at 4250 Hz (2 X 2125) and 31 dB down at 6375 Hz (3 X 2125). This check is not normally required and should only be necessary if problems occur.

Two outputs are provided from the AK-1: an attenuated, high-impedance output of 20 mV rms for typical connection to the high-impedance microphone input on a transmitter, and a 500 ohm, 100 mV rms output that can be used for carbon-microphone inputs, to drive counters, and other high-level applications. Transistor Q7 is used as an emitter-follower isolation amplifier to drive the 100 mV output. When connecting to the 100 mV output, it should be remembered that the coupling capacitor, C9, is electrolytic and leakage inherent in any electrolytic will produce a dc voltage if a very high impedance device is connected to this output. This is particularly true of some counter input circuits and, on counters without a blocking input capacitor, can cause false counting. The cure is to terminate the output in 1K to 10K ohms. Another precaution for use of the 100 mV output is to maintain fairly low shunt capacitance across the output. Under some conditions, transistor Q7 will oscillate in the 5 to 10 MHz range if the 100 mV output is capacitively loaded. The cure is to reduce the capacitance of the load, or use ferrite beads on the leads of Q7. Use of resistor Rx to provide space-tone pre-emphasis is discussed in detail in the applications section of this manual.

Power required by the AK-1 is connected to pins 5 (+12V @ 30 ma) and 1 and 12 (ground return). An additional zener regulator, D3, provides +8.2 volts regulated to the oscillator circuit, but regulation of the +12 volt input is also highly recommended.

4. AK-1 KIT CONSTRUCTION

Construction of the AK-1 involves two steps: assembly of the circuit board and interconnection of the circuit board to a power supply, control switches, connectors, and the rest of the RTTY system. Since there are many ways in which the AK-1 may be interfaced with other equipment, a number of common interconnection schemes are presented and discussed. The constructor should familiarize himself with all techniques discussed and then choose the one that is most convenient for his particular system. Obviously, the circuit board must be assembled in any case and this task may be tackled first.

4.1 Circuit Board Construction

Construction of the AK-1 involves assembly of most of the parts on the circuit board and then installation of the board and its edge connector, switch, and connectors in whatever housing the constructor chooses. Assembly of the circuit board is quite simple and will generally not require more than one hour of construction time. The circuit board layout in Figure 2 and the photograph in Figure 3 (pages 17 and 18) should be closely followed for correct parts placement. The following assembly order is recommended for the circuit board.

First, mount all of the resistors on the circuit board, starting with the four trimming potentiometers. Note that each has different resistance - locate the proper location for each before soldering it in place. The $\frac{1}{4}$ watt fixed resistors can now be mounted in the locations indicated. ALL resistors are mounted in a vertical position with the body of the resistor placed over the hole marked with a "V" on the circuit board layout. Resistor locations marked "R_a", "R_b", and "R_c" are provided for series trimming resistors if required. They are generally not required and jumpers should be inserted in these locations initially. If trimming resistors are found to be required upon alignment, the appropriate jumper can then be replaced by a series resistor. Resistor "R_x" location is provided to allow a limited amount of "pre-emphasis" on the space tone. Choice of this value depends upon the equipment that the AK-1 is used with and this location should be left open until tests indicate what value is optimum. Choice of R_x values is discussed in the alignment and test section of this manual.

The transistors and diodes should now be mounted, being very careful to observe correct transistor orientation and diode polarity. Note that, as with the resistors, ALL diodes are mounted in a vertical position with the body of the diode over the hole indicated.

Place the capacitors on the circuit board next, starting with the ceramic and mylar capacitors first. When mounting the electrolytics, observe the polarity marked on the layout. All electrolytic capacitors are mounted in a vertical position with the body placement indicated as before. The .01 µf polystyrene capacitor should be mounted horizontally in the position indicated.

The two 88 mhy toroidal inductors should be mounted last. The two halves of each toroid are connected in "series-aiding" with the "loose-end" of one half connected to the "sleeved-end" of the other half to form the center-tap. Fasten the toroids to the board with the 6-32 hardware furnished with the kit. The correct order of assembly is: screw-head, flatwasher, nylon washer, toroid, circuit board, lockwasher, and 6-32 nut. The completed assembly should have the screwhead and toroid on the component side of the circuit board. This completes the assembly of the circuit board and it should be set aside until the switch, connectors and power supply have been mounted.

4.2 Installation of the Circuit Board

Since the AK-1 is designed to be used in conjunction with other RTTY equipment, it does not have a self-contained power supply and must therefore be furnished with +12 volts dc at 30 ma. This voltage can be obtained from the demodulator (such as the ST-5 or ST-6) or other low-voltage source. Whatever the source, the +12 volts furnished to the AK-1 should be well-filtered (free of hum and noise) and reasonably well regulated (zener regulation is quite adequate).

The circuit board of the AK-1 should be mounted in a metallic container (for shielding), away from obvious heat and hum sources. When the AK-1 is used with the ST-6, a circuit board location has been reserved in the demodulator cabinet for the AFSK oscillator.

A 12 pin edge-connector is supplied with the AK-1 kit to make connection with the circuit board, but this can be deleted, if desired, and connections made directly to the circuit board at the extra pads provided. This technique will allow the fingers of the board to be cut-off, saving approximately 3/4 inch in overall length (fingers plus edge connector). Also supplied with the kit are two phono pin-jacks for audio output connections and two ¼" phone jacks for hand-key and RTTY keying signal input. A DPDT toggle switch is provided to change the shift of the AK-1. Since the AK-1 requires only one pole of the switch, the other pole may be utilized to change the demodulator shift or other function as desired. Typical connections to the AK-1 are shown in Figure 4.

5. INTERCONNECTION OF THE AK-1 WITH OTHER EQUIPMENT

Interconnection of the AK-1 in the RTTY system involves **two** major points of consideration: (1) where the keying voltage is obtained and (2) how the audio output tones are applied to the transmitter(s). There are obviously a great many techniques that can be used; some of the more popular forms are described in the following.

5.1 Keying the AK-1

To key the AK-1 from mark to space condition, it is required that pin 6 of the edge connector be biased between 0 to -15 volts for mark and +5 to +15 volts for space.

Three simple techniques to derive the required keying voltage are illustrated in Figures 5, 6, and 7 (page 20). The simplest, direct keyboard keying (Figure 5) involves addition of one resistor (4.7 K - furnished) between pins 5 and 6 of the AK-1 edge connector and connection of the teleprinter keyboard between pin 6 and ground (pins 1 and 12). This allows "full-duplex" operation of the AK-1; the keyboard circuit is entirely independent of the printer circuit and both can be operated simultaneously without interference. Since this connection does not easily allow local copy of the transmitted text, it is not generally used for radio-communications teleprinter systems.

A second system, shown in Figure 6, is compatible with most of the older tube-type demodulators. The general form of the demodulator should be as shown with a keyer tube that normally operates with a grounded cathode and with the printer and keyboard in series in the plate circuit. A voltage proportional to the loop current is obtained with the 47 ohm resistor between cathode and ground. Since these keying pulses are inverted with respect to the AK-1 input requirements, the 3.9 K bias resistor and 2N697 inverter stage are also required. As in the direct connection, a 4.7 K resistor is connected between pins 5 and 6 of the AK-1. Any NPN transistor of moderate beta can be used for the inverter, but the 3.9 K biasing resistor·may require adjustment for devices other than the 2N697. It should·be noted that this circuit will also work with any loop system if one point on the loop can be grounded. Since the keyboard and printer are wired in series, this connection allows local copy of the transmitted text.

A third technique that will work with virtually any low-current loop system (up to 100 ma) is shown in Figure 7. A HAL FLI-1 Floating Loop Interface is used to provide complete isolation between the loop circuit and the AK-1. Developed for use as an isolated input option for the HAL RVD-1002, the FLI-1 uses an optical isolator to provide coupling of keying pulses for loop voltages up to 250 volts. The FLI-1 can be purchased separately from HAL Communcations for $10.00.

Since the AK-1 was originally designed to be used with the "Mainline" series of RTTY demodulators, interfacing with the ST-5 or ST-6 demodulator is very simple. Interconnections between the AK-1 and the ST-5 are shown in

Figure 8. Note that use of the two-circuit phone jack for the CW ID Key allows choice of either AFSK or FSK ID modes without internal changes in the wiring. Connections between the ST-6 and the AK-1 are shown in the schematic diagram of Figure 9 and in the cabinet wiring diagram of Figure 10. It is highly recommended that these diagrams be followed exactly when building the ST-6. Factory wired ST-6/AK-1 combinations with serial numbers higher than #168 follow this connection. When installed in this manner in the ST-5 and ST-6, the shift of the AK-1 is controlled by the demodulator shift switch and the AK-1 tones are keyed by anything keying the demodulator loop, including incoming signals as well as by the keyboard. Since the AK-1 tones are always "on" with these connections, the AK-1 output is actually a "regenerated" form of the input signal to the demodulator, conditioned and controlled by all of the processing circuits of the demodulator. This output can be used to great advantage with the ST-6 autostart system if the AK-1 output is recorded on an audio recorder whose start-stop function is controlled by the ST-6 autostart. Since the recorded signal has already been processed by the ST-6, any simple demodulator can be used when the tape is played back.

5.2 Connecting the AK-1 to the Transmitter

There are two audio outputs from the AK-1, one with an output level of 100 mV rms and 500 ohms internal impedance (pin 8) and one with an output level of 20 mV rms (pin 11) to drive high-impedance microphone-inputs of transmitters. To avoid hum (and excessive cable capacitance) the audio cables between the AK-1 and the transmitter should not be longer than three feet.

The AK-1 can be used to directly modulate an AM or FM transmitter to produce type A2 or F2 emissions. This is the classically "standard" application of an AFSK oscillator, and the AK-1 generates the AFSK standard tone convention of 2125 Hz mark (lower-frequency tone) and 2295 Hz (170 Hz shift) or 2975 Hz (850 Hz shift) space with a high degree of accuracy. Since these modes are authorized for amateur communications on frequencies above 50.1 MHz, this technique is generally restricted to VHF operations. Either (or both) output can be connected to the appropriate place on the VHF transmitter and the transmitter audio gain adjusted for proper modulation level. Note that some VHF FM transmitters in particular are not designed for continuous transmitter-on operation and may over-heat if the transmitter power is not reduced for RTTY operations.

A second use of AFSK oscillators in radio communications systems has been gaining increasing popularity; connection of AFSK tones to a SSB transmitter to generate type F1 FSK emissions. Because of bandwidth restrictions, the only legal mode for amateur transmission of RTTY signals in the 3.5 to 30 MHz frequency range is type F1 emission. A standard way to generate F1 emission is to frequency-shift-key (FSK) an oscillator in the transmitter system with the RTTY pulses. A second technique that can be used to produce a type F1 emission is to use an AFSK oscillator with a SSB-type of radio transmitter. An understanding as to why this "AFSK"

technique works and what some of the potential problems are is the object of the following discussion.

First, it is best that the basic requirements and standards of type F1 RTTY emission for amateur ratio (as well as most other HF services) be understood. A basic requirement by the FCC is that F1 is "telegraphy by frequency shift keying . . . one of two frequencies being emitted at any instant" - two frequencies maximum, only one-at-a-time. (FCC Rules & Regulations, Vol. II, Part 2, Section 2.201 (f), Sept., 1972.) A further convention for HF transmission of RTTY signals is that the higher of the two frequencies is the rest condition of mark condition. Note that this is the reverse of the VHF standard of the lower modulating tone being the mark tone.

Now, consider the typical filter-type of SSB transmitter shown in Figure 11. For the sake of simplicity, it will be assumed that no heterodyning of the original signal is required and that the SSB signal is generated directly at the output frequency. Therefore, the carrier frequency, generated in the BFO stage is combined with the audio in a balanced modulator to produce a double-sideband supressed-carrier signal. This signal is then passed through a "steep-skirted" filter and only one of the two sidebands, the lower sideband, is passed on to the amplifier and then to the antenna. This sideband generating and selecting process is illustrated for a voice signal in the spectrum diagrams in Figure 11. If audio tones are substituted for the voice signal and subjected to the same processing system, the upper set of spectra will be generated to each stage. It is therefore apparent that introduction of two discrete audio tones into a SSB transmitter has resulted in the generation of two discrete radio frequencies at the transmitter output. Also apparent is the fact that although the mark tone was the lower frequency of the audio tones introduced, the radio frequency produced by the SSB transmitter from this mark tone is higher in frequency than that for space condition. This is because of the sideband inversion of the LSB mode; if the upper sideband had been selected, no sideband inversion would have occurred and the radio frequency corresponding to mark condition would have been lower than that for space. Since it is usually desirable to conform to the standard of mark being the higher frequency, the LSB mode is generally used so that the same AFSK oscillator can be used for both VHF and HF operations without an inverting switch. Another result of the SSB technique is that the frequency of the mark signal is not the same as that of the carrier and therefore the transmitter dial. The transmitter dial does not then indicate the true frequency of the RTTY signal and a correction must be made to determine the actual frequency.

When the actual spectrum of the SSB signal is considered in greater detail as shown in Figure 12, other problems become apparent. As shown in Figure 12a, the BFO frequency of a voice LSB transmitter is placed with respect to the filter pass-band so that the audio spectrum of 300 Hz to 2400 Hz corresponds to the -3 dB response points of the filter. Note that there is only a little more than 20 dB of carrier suppression contributed by the filter. Although another 20 to 30 dB of carrier suppression can

reasonably be expected from the balanced modulator, a little carrier leakage on a voice SSB signal is of little concern since single-sideband voice with a carrier is just as legal as single-sideband voice without a carrier.

If the normal RTTY tones of 2125 Hz (mark) and 2295 Hz or 2975 Hz (space) are connected to the SSB transmitter the output of Figure 12b results. Obviously, wide-shift operation is out of the question if the filter is very good at all since the 2975 Hz output is down from the 2125 Hz level by approximately 36 dB in this example. Note, however, that there is little differential attenuation between the two narrow shift frequencies, suggesting that operation on at least 170 Hz shift is possible. (The amount of differential attenuation will be controlled by the "squareness" of the "corner" of the filter response curve.) But, also note that the carrier suppression is the same as for voice operations.

Because generation of more than one frequency at a time is contrary to the FCC definition of type F1 emission, any carrier that is radiated is considered to be a spurious emission. The exact definition of what is a spurious signal depends upon many factors and interpretations but since they are all generally based upon potential interference to other users a good practice to follow would be to assure that such signals cannot be heard at another station. Since this is obviously controlled by power level, distance between transmitter and receiver, receiver sensitivity and a lot of other hypothetical considerations, the most practical approach is to reduce any spurious signals to as low a level as possible.

Fortunately, a fairly simple modification of the SSB transmitter will allow both a considerable increase in the carrier rejection of the filter and permit wide-shift operation. The modification is to change the frequency of the BFO for LSB mode so that the RTTY tones are now centered in the filter passband. For a typical SSB transmitter with a 2.1 kHz filter, this amounts to changing the BFO frequency by approximately 1200 Hz from its voice operation frequency. This procedure is indicated in Figure 12c. Note that now all three RTTY frequencies pass through the filter unattenuated and that the carrier rejection of the filter is greater than 60 dB. Proper procedure to determine the correct RTTY BFO crystal frequency is:

1. Locate the LSB BFO crystal, note its frequency and whether it is lower or higher in frequency than the filter.

2. Choose a new crystal frequency that is approximately 1200 Hz further away from the filter center frequency than the original LSB crystal.

3. Order a good, commercial-quality crystal for this frequency - don't buy a general purpose, low-cost crystal - it will probably drift.

An alternate approach that can be used if the center frequency of the filter is known is to choose a crystal frequency that is 2550 Hz (center between 2125 and 2975 Hz) away from the filter center frequency, in the same

10

direction as the original LSB crystal. Often a switch or socket can be installed in the transmitter so that LSB voice or RTTY operation can be selected at will. This procedure will work well with most filter-type heterodyne SSB exciters. However, it may not be possible to make this crystal change in equipment in which the BFO crystal frequency is used more than once in the heterodyne scheme or in some systems that switch filters instead of BFO crystals to change sidebands (some Drake equipment). The exact form the modification takes is up to the individual and HAL Communications Corp. assumes no responsibility for any such modifications.

It should be noted that use of the AFSK-SSB system to generate RTTY signals is NOT RECOMMENDED with phasing types of SSB transmitters because of their relatively poor stability. Radiation of spurious signals is highly probable with such equipment.

Another AFSK-SSB RTTY generation scheme that is not recommended is the use of "low-tones", AFSK tones of lower frequency. Referring to Figure 12b, it can be seen that if the frequency of the audio tones were lowered to say 1275 Hz mark and 1445 Hz or 2125 Hz space, all tones would easily pass through the filter and modification of the SSB transmitter would not be required. Although this is at first very attractive, it has the following serious defects:

1. The carrier suppression is the same as for voice, not necessarily desirable as discussed earlier.

2. Harmonics of the lower tones, particularly the 2nd harmonics of 1275 and 1445 Hz, will be radiated with little attenuation by the filter. These harmonics can be easily caused by distortion in the SSB transmitter itself.

3. The unwanted-sideband suppression of SSB transmitters is greatest for high audio frequencies and less for lower frequencies.

4. The percentage-change in frequency is much greater, particularly for wide-shift. This means that low-pass filters for the AFSK oscillator and bandpass filters for the demodulator (if transceive operation is used) are very difficult to design and considerably more complicated. A relatively simple transmitter modification is therefore traded for a complex redesign of both the AFSK oscillator and demodulator.

It can therefore be concluded that, if possible, the BFO frequency for LSB mode should be shifted to optimize RTTY operations and that, if this is not possible, the unmodified transmitter can be operated with 170 Hz shift (but not 850 Hz shift) if care is taken to check the carrier suppression often. Use of phasing-types of SSB transmitters or "low-tones" is not recommended.

Another consideration in the use of SSB transmitters for RTTY transmission is that this equipment has usually been designed specifically

11

for voice operation and power supply and output tube power ratings may not handle the 100% duty cycle of RTTY. The power rating of each transmitter varies with manufacturer, but few SSB transmitters will last long operating at full power in RTTY mode. The manufacturer of the transmitter under consideration should be consulted to determine proper operating parameters for 100% duty cycle operation.

A problem noted with some SSB transmitters is that in addition to placing the BFO frequency optimally for voice operation, the frequency of the audio circuits has also been restricted to 300 to 2400 Hz. This can generally be cured by changing the audio circuit slightly (usually a capacitor in the coupling circuits between stages) or by pre-emphasis of the tones. As discussed earlier, resistor Rx allows a limited amount of space-tone pre-emphasis for wide-shift tones. The proper adjustment procedure would be to measure the transmitter power output for mark and space (850 Hz shift) and decrease the value of Rx until the two powers are the same. The powers at both frequencies will be affected by changing the resistance and it is impractical to try to compensate for more than 2 dB of differential signal power with this technique. No compensation should be required for 170 Hz shift since both tones should be well within the pass-band of the filter.

6. TEST AND ALIGNMENT

Refer to the schematic diagram, Figure 1, and the circuit board layout, Figure 2, to locate the test points mentioned in the following procedure.

After the AK-1 circuit board and related connectors and power supply have been wired, apply power to the oscillator and check for the presence of +12 volts dc at pin 5 of the edge connector and for +8.2 V dc at the emitters of Q_2 and Q_3. The total current drain from the +12 volt power supply should be of the order of 30 ma $\pm$ 5 ma. If the voltages are not correct or if the current consumption is wrong, a mistake in wiring has been made and should be located and corrected before proceeding. If an oscilloscope is available, proper operation of the oscillator and bistable multivibrator (BSMV) can be checked. The waveform across the 0.01 μfd polystyrene timing capacitor should be a saw-tooth of approximately two-times the desired output frequency and the waveforms at the collectors of either Q_5 or Q_6 should be square waves of the same frequency as the output. The waveform at the base and emitter of Q_7 should be a sine-wave at the output frequency.

If an oscilloscope is not available, the 100 mV output of the AK-1 can be coupled to a RTTY demodulator and the tones adjusted to the frequencies of the demodulator. Generally, there should be little trouble with the AK-1, experience has shown that 99% of problems with the AK-1 can be traced to wiring errors.

After it is determined that the AK-1 is functioning correctly, the frequencies of the tones should be checked with a frequency counter. The counter should be connected to the 100 mV output. Note that some counters (such as the Heath IB-101) have a very high input impedance and no blocking capacitors. In this case, the very small, but finite, leakage in electrolytic capacitor C_9 can place a dc potential at the counter input and cause no indication or faulty indication. It is therefore recommended that the 100 mV output be terminated in 1000 ohms when aligned in this manner. Always adjust the AK-1 in the mark condition first and then adjust the two space tones. Therefore, set the input keying signal for marking condition and adjust R_{12} and R_{13} for an output of 2125 Hz. Note that R_{13} is a coarse adjustment and R_{12} is a fine adjustment for the mark tone. The mark tone should be 2125 Hz for either shift.

Now place the shift switch in the 170 Hz position and set the keying input for a space condition. Adjust R_6 for an output frequency of 2295 Hz. Change the shift switch to 850 Hz and adjust R_4 for an output frequency of 2975 Hz. Check the amount of CW ID shift by returning the keying signal to the mark condition and shorting the key jack - the frequency should shift to approximately 2225 Hz in either position of the shift switch. This frequency can be adjusted by changing the value of R_8, but this is normally not necessary. As discussed previously, resistor locations R_a, R_b, and R_c have been provided to allow further trimming of the total series resistance for each tone if necessary. Experience has shown that the ranges of the

13

potentiometers are sufficiently great to account for component tolerances and it should therefore be possible to adjust all of the tones directly without changing or adding resistors.

The low-pass filter requires no adjustment. Proper performance is indicated by comparing the output voltage for 2125 Hz with that of 2975 Hz. The two levels should be within 0.5 dB of each other if the filter is performing correctly. As mentioned earlier, resistor location R_x is provided to allow a small amount of space-tone pre-emphasis. The audio stages of some transmitters may tend to have slightly reduced output of 2975 Hz as compared with 2125 Hz. Insertion of a resistor at R_x forms a single-pole low-pass filter with C_{10} and can, in some cases, provide some compensation of the low-level space carrier output. It should be noted, however, that both tones will suffer some attenuation and it is impractical to try to compensate for more than a 2.0 dB difference in levels with this technique.

When the HAL AK-1 is constructed as a part of the HAL ST-6, the alignment procedure can be somewhat modified and portions of the ST-6 used in the test. After it is determined that supply voltages and currents are correct and that the oscillator is functioning correctly, connect the 100 mV output of the AK-1 to the audio input of the ST-6. Put the ST-6 AUTO-STAND-BY switch in STAND-BY position and the LIMITER switch in the ON(FM) position. Connect the frequency counter to pin 8 of the edge connector of the number 1 board for the shift under test (i.e., for the 170 Hz shift, connect the counter to 1-170(8) and for 850 Hz shift to 1-850(8)). This technique has the advantage that the input bandpass filter and limiter stages of the ST-6 serve as counter input stages, reducing noise, increasing signal strength, and improving accuracy of the measurement. With the controls set in this fashion and the printer jack of the ST-6 unconnected to anything (self-shorting), the AK-1 is in the mark condition and the 2125 Hz tone can be adjusted as before. To obtain the space condition, plug an unconnected plug into the ST-6 printer jack, opening the loop. Now adjust the space tones - note that it is necessary to move the counter connection point from one board no. 1 (pin 8) to the other when changing shifts.
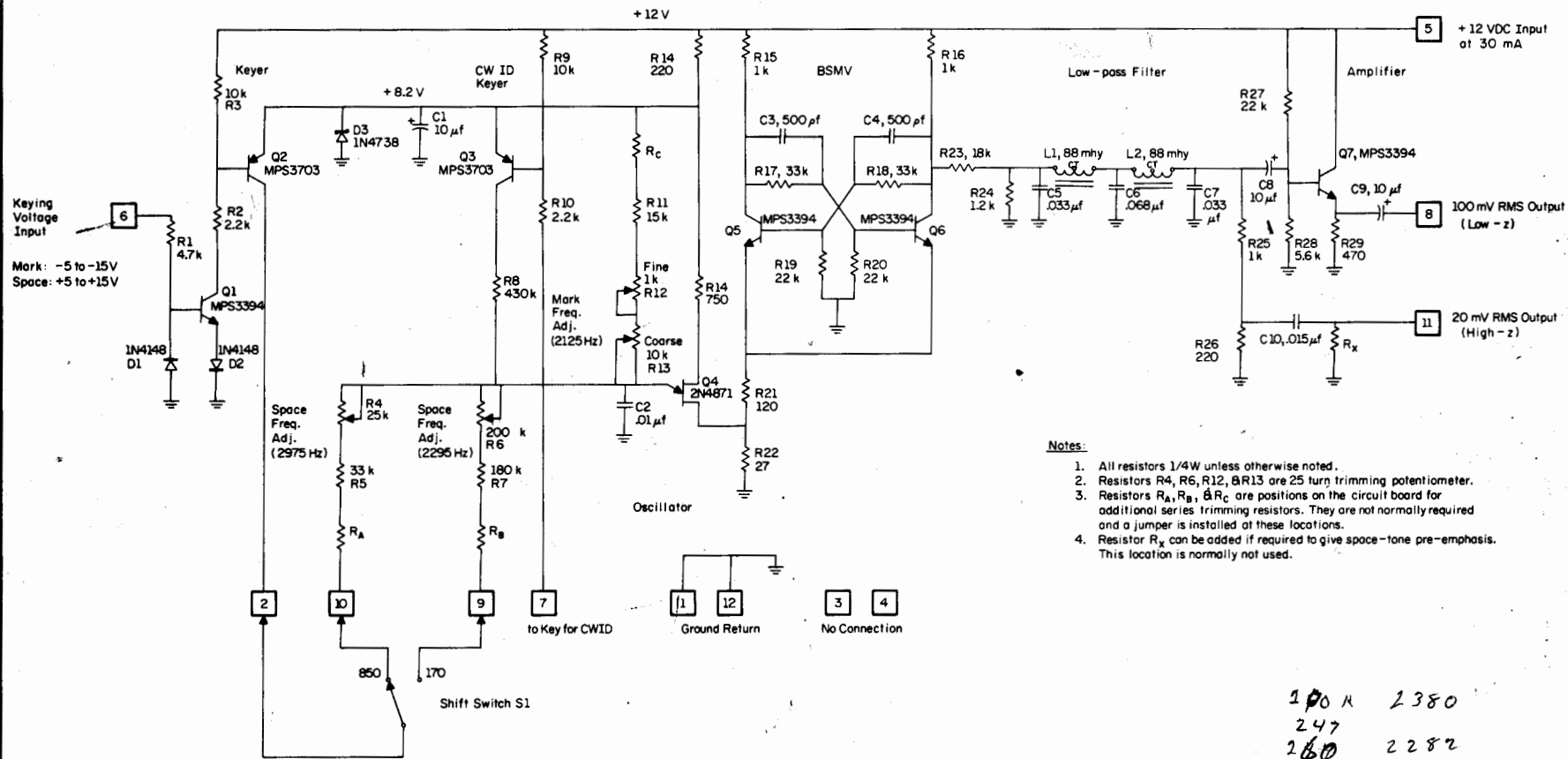
An interesting variation of this technique is that the AK-1 can be used to check the center-frequency of the ST-6 discriminators by simply observing the frequencies at which peaks on the ST-6 tuning meter occur.

14

7. DIAGRAMS AND PHOTOGRAPHS

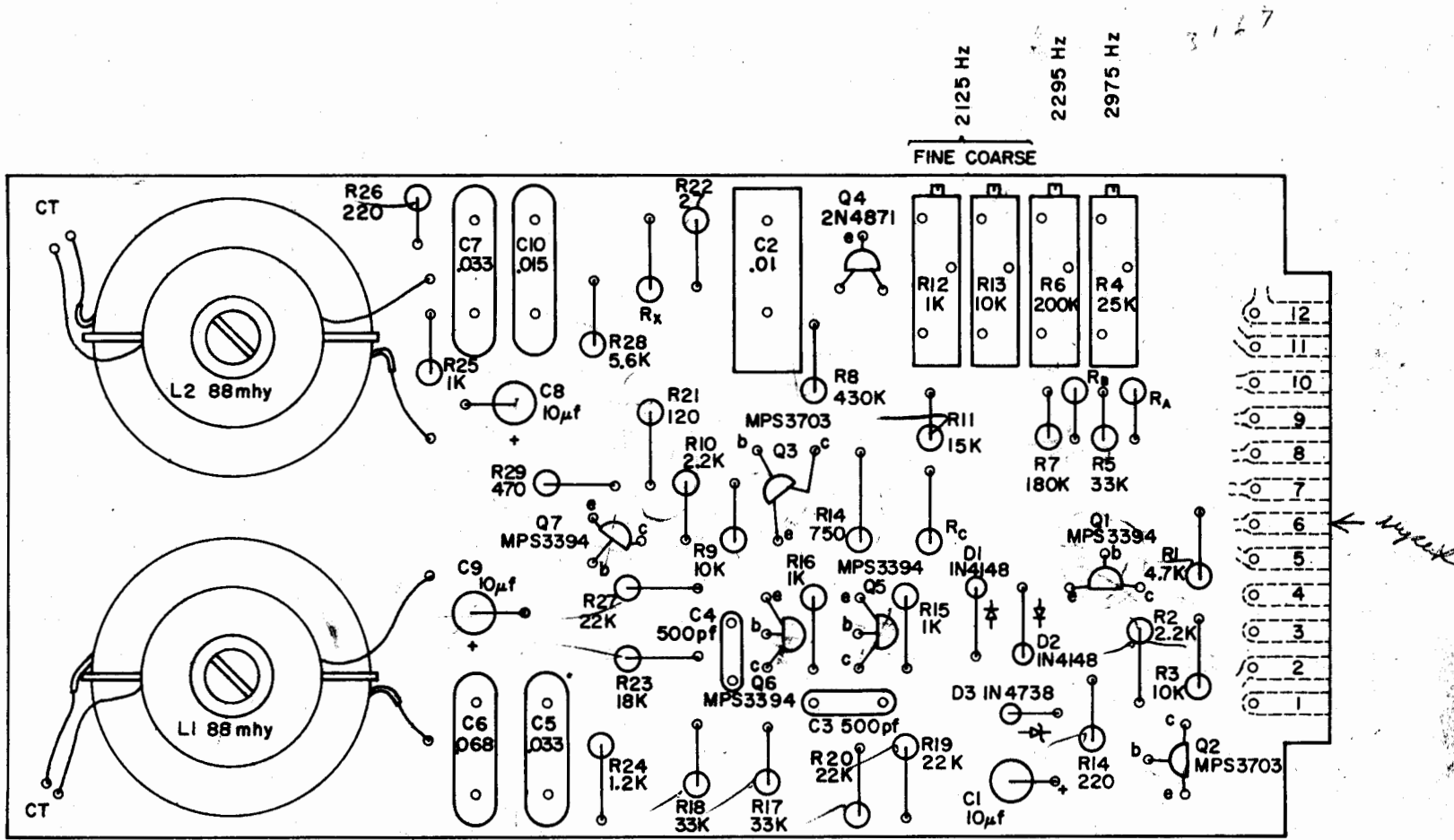The schematic diagrams, parts layout and circuit board photographs are shown on the following pages.

Figure 1.   AK-1 Schematic Diagram

Figure 2. AK-1 Circuit Board Layout

-17-

FINE COARSE

2125 Hz 2295 Hz 2975 Hz

CT

R26 220
C7 .033 C10 .015
R25 1K
C8 10µf +
L2 88mhy
R22 2.7
C2 .01
Q4 2N4871
R12 1K R13 10K R6 200K R4 25K
R28 5.6K
Rx
R8 430K
R11 15K
R_B R_A
R21 120
R10 2.2K
MPS3703
Q3
R7 180K R5 33K
R29 470
Q7 MPS3394
R9 10K
R14 750
Rc
Q1 MPS3394
C9 10µf +
R16 1K
MPS3394
D1 1N4148
R1 4.7K
R27 22K
C4 500pf
Q5
R15 1K
R2 2.2K
R23 18K
Q6 MPS3394
C3 500pf
D2 1N4148
R3 10K
D3 1N4738
L1 88mhy
C6 .068 C5 .033
R24 1.2K
R20 22K R19 22K
R14 220
Q2 MPS3703
R18 33K R17 33K
C1 10µf

CT

12 11 10 9 8 7 6 5 4 3 2 1

NOTES:
1. REFER TO SCHEMATIC FOR EDGE-CONNECTOR PIN CONNECTIONS.
2. RESISTORS R_A, R_B, & R_C ARE LOCATIONS FOR TRIMMING RESISTORS IF NEEDED.
   NORMALLY, THESE RESISTORS ARE NOT REQUIRED AND A JUMPER IS PLACED IN THEIR LOCATION.
3. RESISTOR R_X CAN BE USED TO PROVIDE A SMALL AMOUNT OF SPACE-TONE PRE-EMPHASIS.
   CONSULT THE MANUAL FOR SELECTION TECHNIQUES.

AK-1
EDGE CONNECTOR

12

11 ——————— J1 20 mV RMS OUTPUT
                     (HIGH-z)

10

SHIFT   850   170   9
SWITCH   S1

                             8 ———— J2 100 mV RMS OUTPUT
                                              (500 ohms)

                             7

J4   6
KEYING VOLTAGE   .001
INPUT

                             5

                             4   NC

                             3   NC   .001   J3

12 V D.C.   +   NC   CW-ID KEY
30 ma   .001   2

          −   1
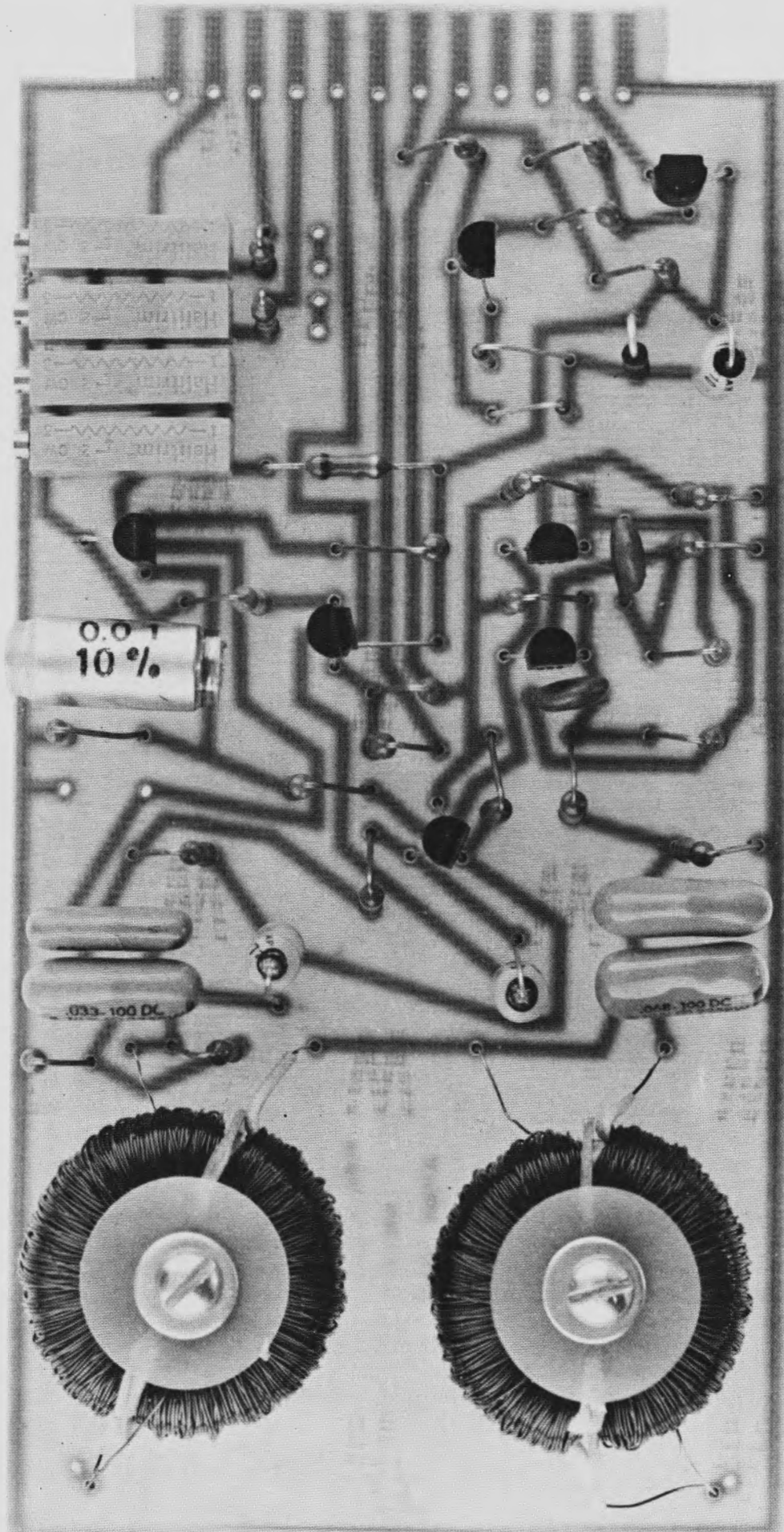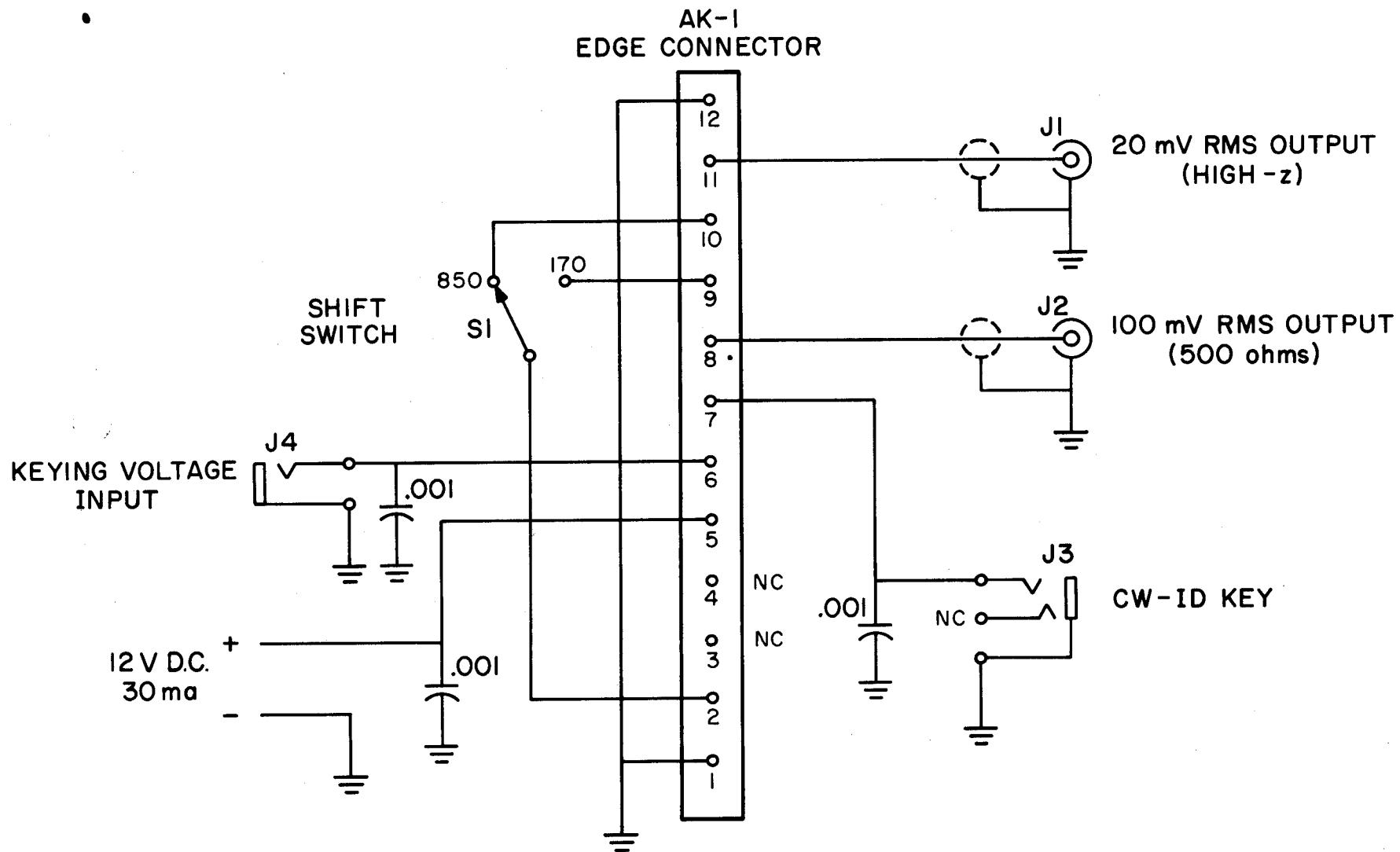
Figure 4   Typical Connections to AK-1

TTY KEYBOARD

4.7 k

5

6 } TO AK-I

1,2
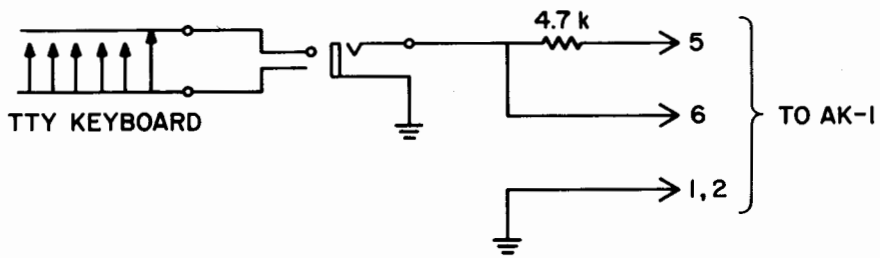
Figure 5   Direct TTY Keyboard Connection to AK-I

B+

TO PRINTER
AND KEYBOARD
(IN SERIES)

ADD THESE
PARTS

KEYER TUBE

4.7 k

5

6 } TO AK-I

3.9 k

2N697
OR EQUIV.

BREAK THIS
CONNECTION

47

1,2
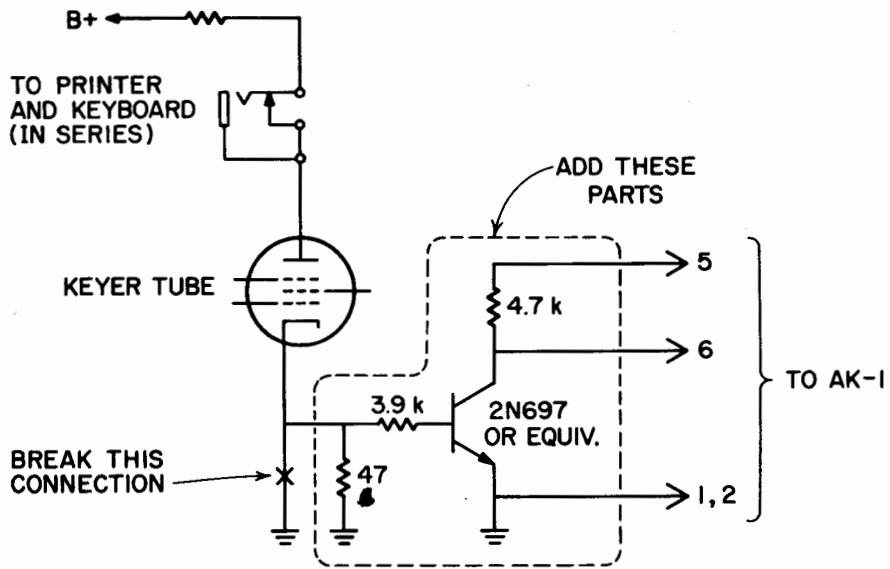
Figure 6   AK-I Connection to Tube-type Demodulator

HAL FLI-I

4.7 k

5

6 } TO AK-I

TO 60 ma LOOP
(POLARITY NOT
CRITICAL)

1,2
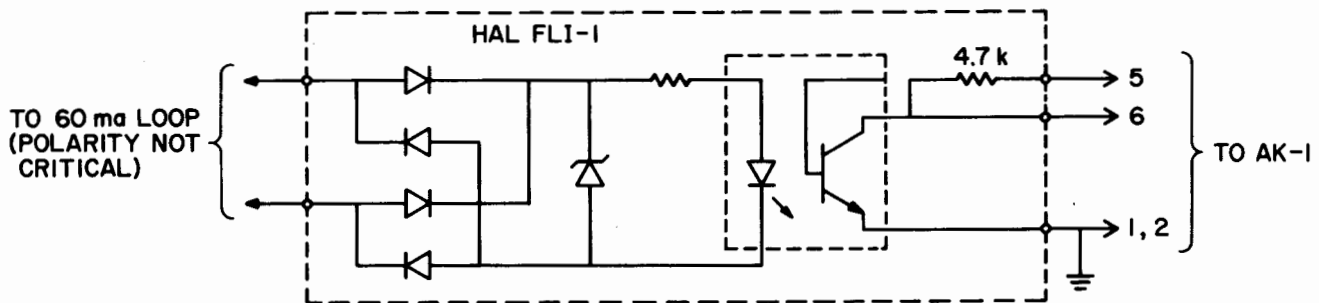
Figure 7   Direct Loop Connection of AK-I

20
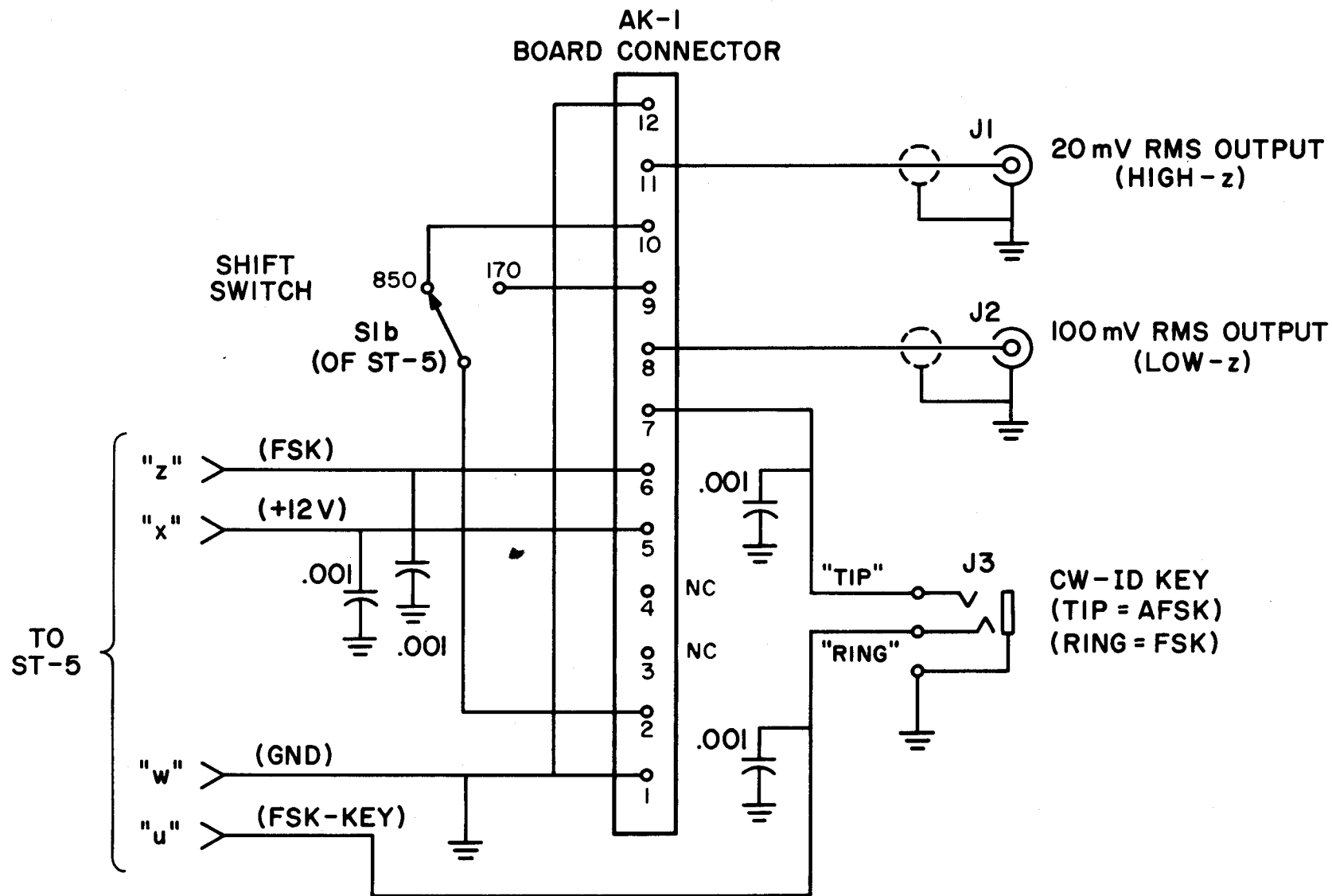
Figure 8   AK-1 Connections to ST-5

21

Figure 9. AK-1 Connections to ST-6
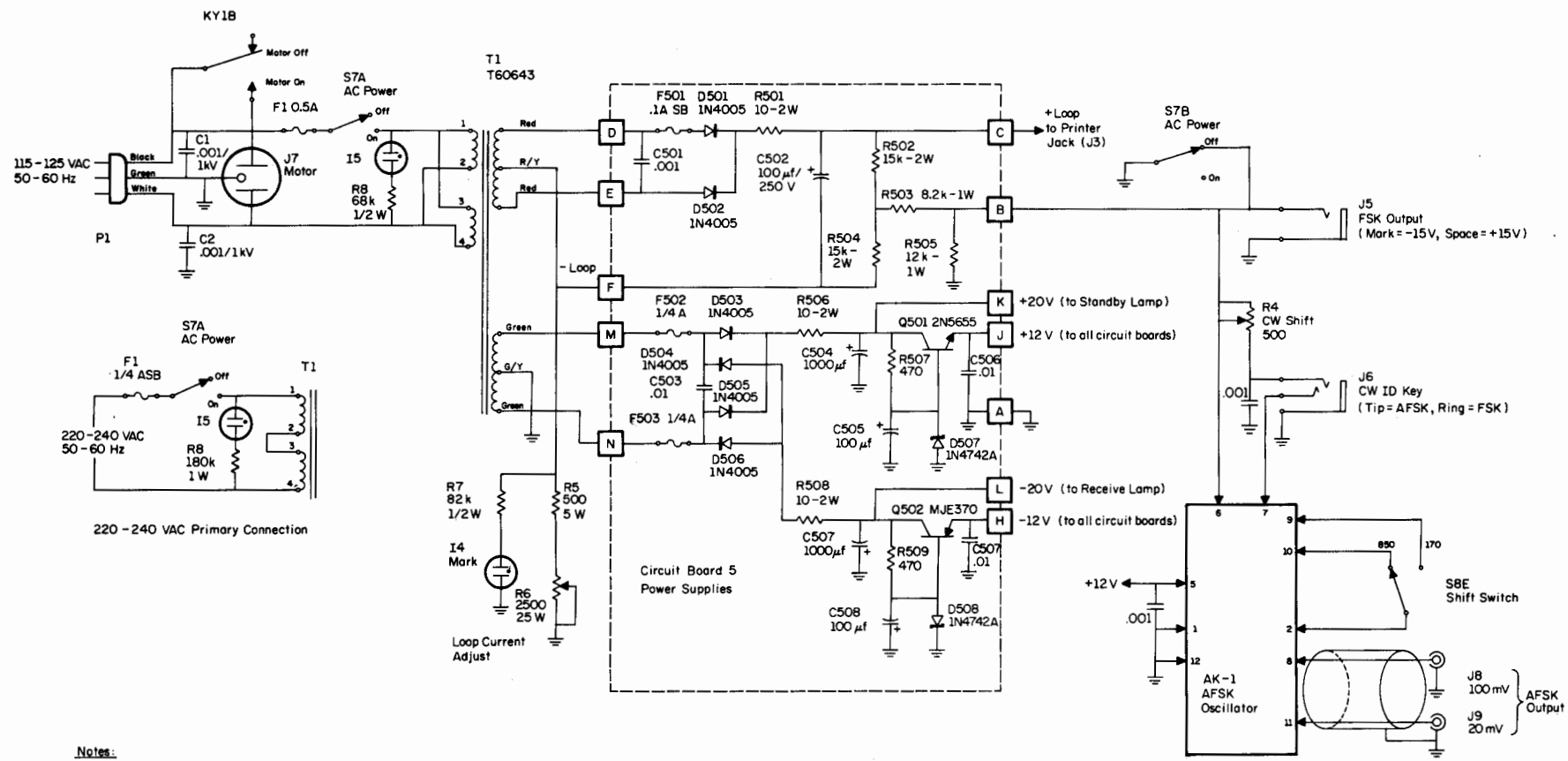
Notes:

1. All resistors 1/4 W unless otherwise noted.
2. Resistor R6 dissipates 9 Watts under Mark conditions and should be heat-sinked by mounting on metallic panel.
3. I-3, I-4, & I-5 are NE-2 type neon lamps.
4. Component Numbering System:
   X001 – X099, Main Frame
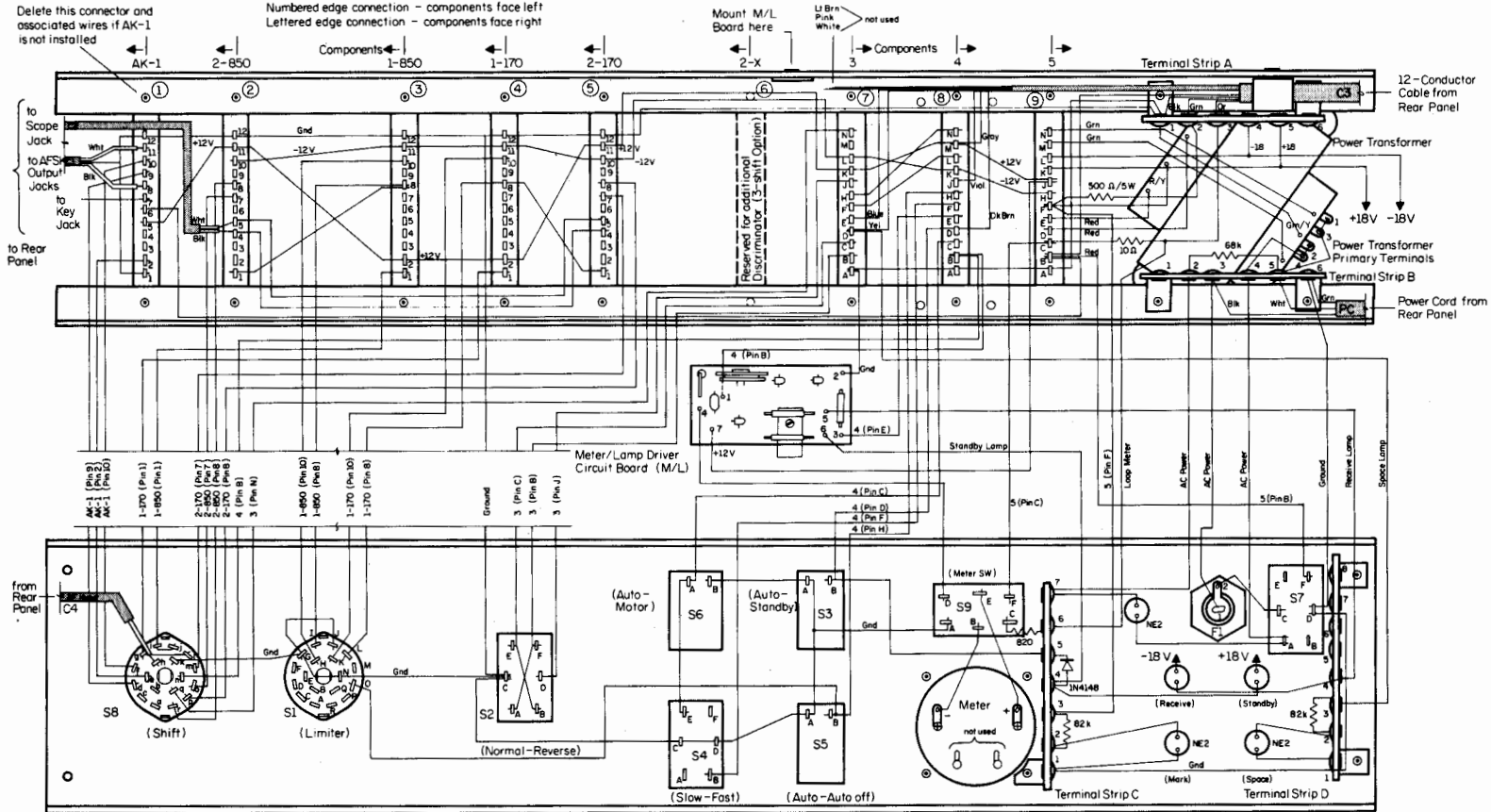   X501 – X599, Circuit Board 5

HAL COMMUNICATIONS CORP.
BOX 365, URBANA ILLINOIS, 61801

ST-6 Demodulator
Circuit Board 5

| DATE | July 8, 1972 | SCALE | — |
| APPROVED | | No. | ST-6, S3 |

Figure 10.   AK-1 Wiring in ST-6 Cabinet
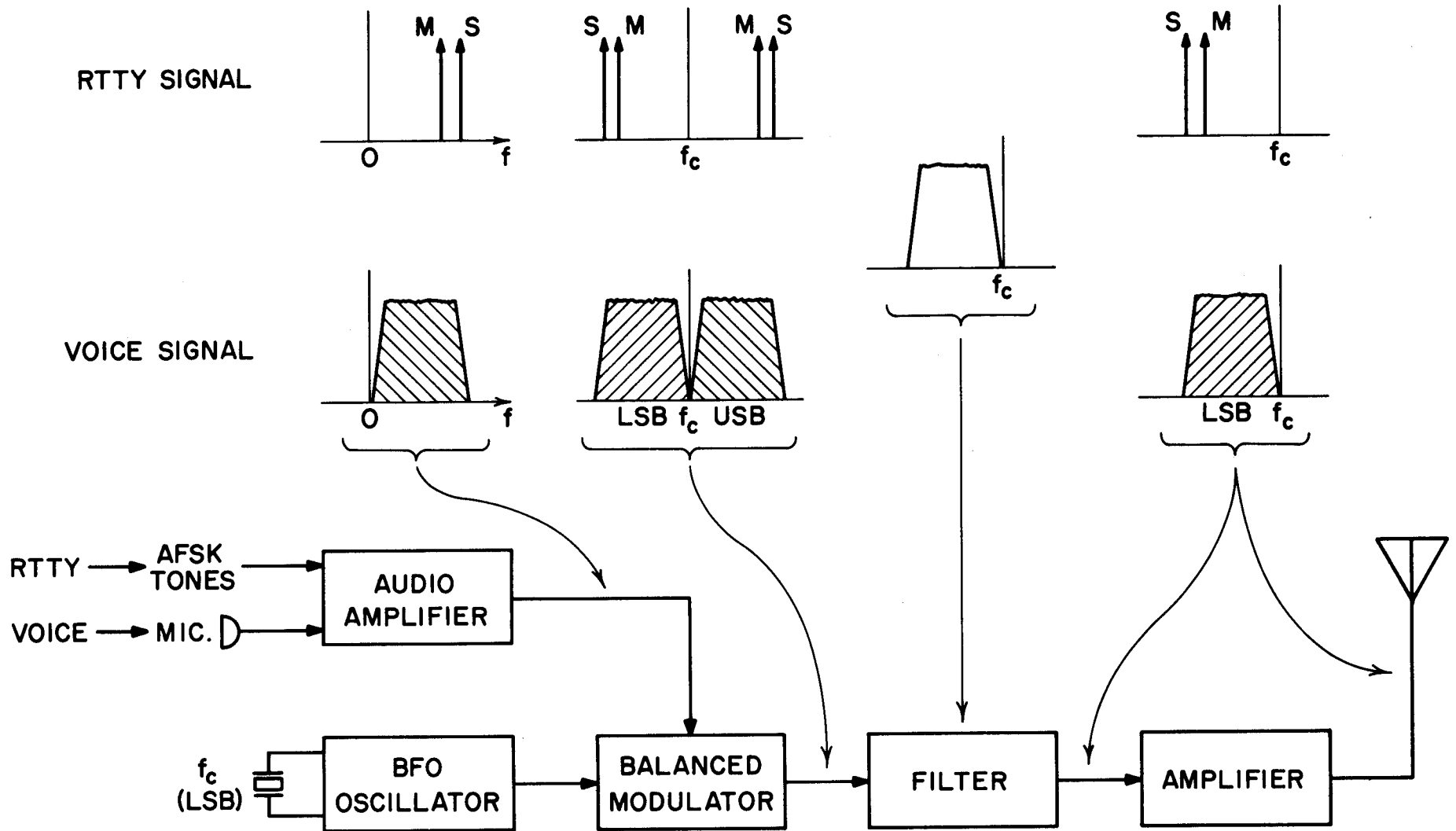
Figure 11   Use of AFSK with a Typical SSB Transmitter

a) LSB Voice Generation in HF SSB Transmitter

b) RTTY Generation Using Tones with an Un-modified HF LSB Transmitter (Usable Only for 170 Hz Shift)

c) RTTY Generation Using Tones with a HF LSB Transmitter Modified by Shifting the BFO Frequency (Recommended Technique)
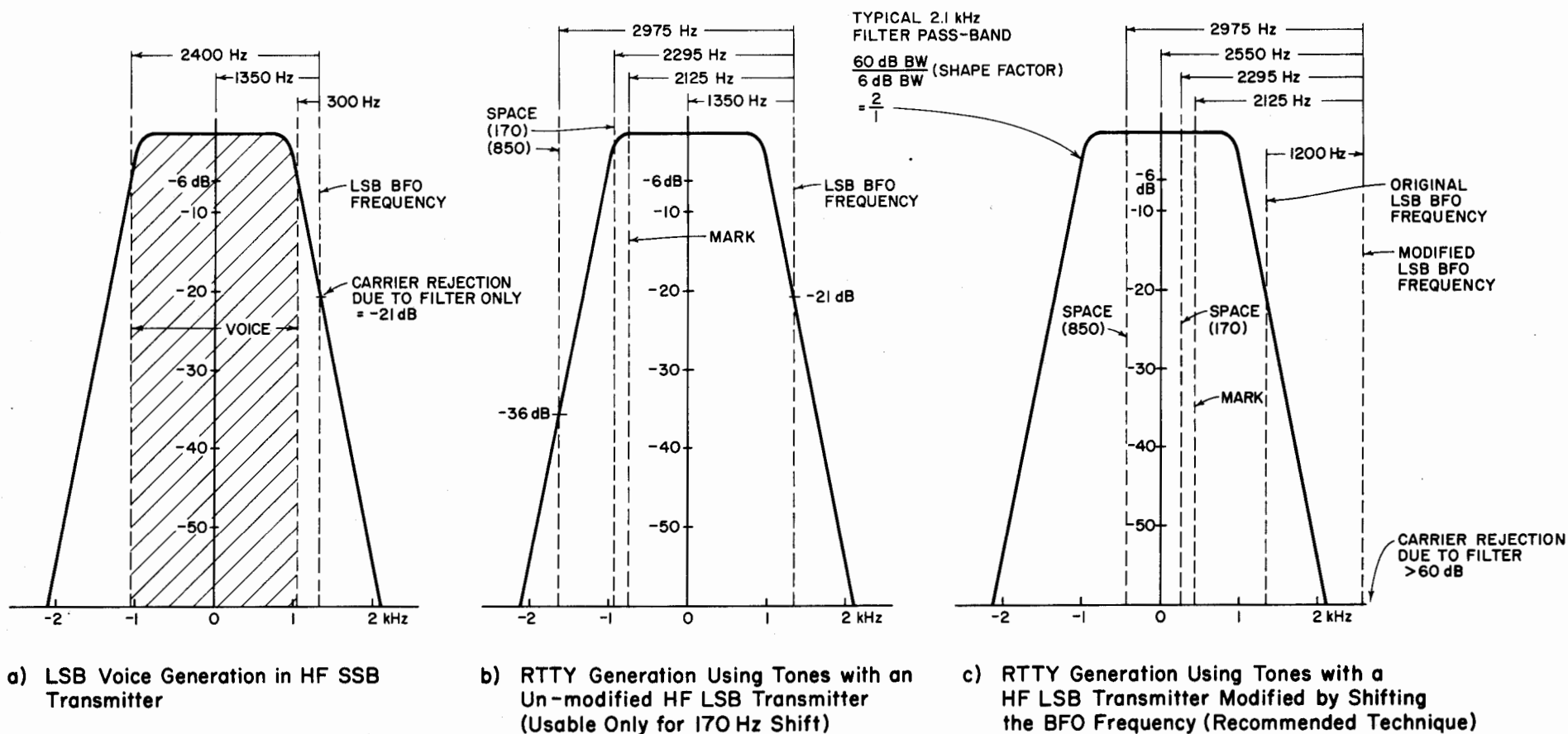
Figure 12   Spectra of Signals Generated by SSB Transmitter

8. PARTS LIST

Resistors

1 - 27 ohm
1 - 120 ohm
2 - 220 ohm
1 - 470 ohm
1 - 750 ohm
3 - 1 K
1 - 1.2 K
2 - 2.2 K
2 - 4.7 K (1 for interfacing)
1 - 5.6 K
2 - 10 K
1 - 15 K
1 - 18 K
3 - 22 K
3 - 33 K
1 - 180 K
1 - 430 K

Capacitors

2 - 500 pf disc ceramic
4 - 0.001 µf disc ceramic
1 - 0.01 µf polystyrene
1 - 0.015 µf mylar
2 - 0.033 µf mylar
1 - 0.068 µf mylar
3 - 10 µf @ 16 V electrolytic

Semiconductors

2 - silicon signal diodes 1N4148
1 - 1N4738 Zener diode
4 - MPS3394 NPN transistor (Q1,Q5,Q6,Q7)
2 - MPS3703 PNP transistor (Q2,Q3)
1 - 2N4871 unijunction transistor (Q4)

Trim-pots

1 - 1 K (2125 Hz fine adj.)
1 - 10 K (2125 Hz corase adj.)
1 - 25 K (2975 Hz adj.)
1 - 200 K (2295 Hz adj.)

Miscellaneous

1 - 3" x 6" Circuit Board
1 - 12 pin Cinch 50-12A-20 Edge Connector
2 - phono jacks & plugs (AF outputs)
1 - ¼" phone jack, 1 circuit (keyed TTY input)
1 - ¼", 2-circuit phone jack (Hand Key)
2 - 88 mhy toroids
1 - DPDT toggle switch (shift switch)
2 - 6-32 screws, 1" L
2 - 6-32 nuts
2 - #6 lockwashers
2 - #6 flatwashers
2 - nylon insulating washers
1 - Manual