

ST-5000

DEMODULATOR

**INSTRUCTION
MANUAL**



HAL COMMUNICATIONS CORP.

BOX 365

URBANA, ILLINOIS 61801

QUALITY COMMUNICATIONS EQUIPMENT

HAL ST-5000 FSK DEMODULATOR / KEYER

TECHNICAL MANUAL

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HAL ST-5000 DEMODULATOR

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I. INTRODUCTION

The Hal Communications Model ST-5000 is a high performance FSK demodulator and tone keyer designed for use with radio teleprinter systems. The ST-5000 incorporates the features and performance characteristics of previous HAL demodulators as well as offering some features previously not available.

The ST-5000 is an audio tone type of demodulator and keyer. Audio tones from the receiver, representing the "mark" and "space" teleprinter code states, are converted into keying pulses by the demodulator section. Active discriminator filters are used in the ST-5000 so that a wide range of input frequencies can be accommodated. Two standard audio tone sets are normally stocked by the factory. The standard tone sets are based on a mark frequency of 1275 Hz ("low-tone" set) or a mark frequency of 2125 Hz ("high-tone" set) for frequency shifts of 170 Hz and 850 Hz. The tone keyer section of the ST-5000 generates the same set of tones for transmitting in addition to a narrow-shift tone for Morse code identification.

The demodulator uses a wide bandwidth limiter and active detector circuit to give outstanding performance for a wide range of input signal amplitudes. A three pole active lowpass filter follows the detector stages to reduce the post-detection noise bandwidth.

The ST-5000 autostart circuit senses the presence (or absence) of a valid teleprinter signal. If the input signal is not recognized as a teleprinter signal, the printer is held in the "mark-hold" condition. If more than twenty seconds pass without recognition of a valid signal, the power to the printer motor is removed.

As mentioned earlier, the tone keyer generates the same tone set as is used in the demodulator section to assure true "transceive" conditions. The tone keyer will also generate an additional narrow-shift tone that can be connected to an external keyer circuit for Morse code identification. All tones of the tone keyer are derived from a type 55 IC oscillator. The output signal is a low distortion sinewave generated in a digital-to-analog converter and then filtered in an active low-pass filter. A wide range of output amplitude (into 500 ohms) is available from the ST-5000, adjustable with an internal control. The shift of the tone keyer is controlled by the front panel SHIFT switches. The SENSE switch (NORM - REV) controls only the demodulator, not the tone keyer.

The audio input to the demodulator and the audio output from the tone keyer are both 500 ohms unbalanced with respect to ground. The oscilloscope signals for a crossed-ellipse oscilloscope display are connected to a rear panel connection. The ST-5000 is furnished with a front panel tuning meter.

Internal, electronically regulated ± 12 volt power supplies provide operating voltages for the demodulator, control, and tone keyer sections of the ST-5000; a 175 volt, 60 ma. loop power supply is also included. The main power transformer of the ST-5000 can be connected for operation with either 105 to 125 VAC or 210 to 250 VAC, 50 or 60 Hz power sources. The power line fuse is accessible from the rear panel of the unit. The ST-5000 requires approximately 20 watts of AC power and is housed in an attractive

blue and beige cabinet that matches the HAL Communications DS-3000 and DS-4000 KSR and R0 Video Display Terminals.

A complete set of connectors are furnished with the ST-5000 to simplify the initial installation. If you are anxious to try your ST-5000, it is suggested that you skip to sections 3.1 and 3.2 of the installation chapter and then read sections 4.1 and 4.2 of the operation chapter before turning the equipment on. The balance of this manual should then be studied before attempting any "custom" connections.

2. SPECIFICATIONS

Input Section:

Data:	Serial, tone-encoded data, up to 110 baud
Input Amplitude:	-60 to +20 dBm (approx. 1mV to 10V rms)
Input Impedance:	500 ohms, unbalanced
Input Frequencies:	
"Low-tones"	Mark = 1275 Hz Space = 1445 Hz (170 Hz shift = "NARROW") Space = 2125 Hz (850 Hz shift = "WIDE")
"High-tones"	Mark = 2125 Hz Space = 2295 Hz (170 Hz shift = "NARROW") Space = 2975 Hz (850 Hz shift = "WIDE")

Discriminator Filter Bandwidth: 190 Hz

Tone Keyer Section:

Data:	Serial data from loop circuit, up to 110 baud
Output Amplitude:	Variable from -40 to 0 dBm (approx. 10mV to 1.00V)
Output Impedance:	500 ohms, unbalanced
Output Frequencies:	Same as those given above for input section plus:
CW-ID:	1175 Hz ("Low-tones"), key down 2025 Hz ("High-tones"), key down

Autostart Section:

Print-control response:	2 to 4 seconds
Motor turn-off time:	20 to 40 seconds
Motor control:	Relay switched power line voltage to accessory socket; up to 8.0 amperes (1/4 HP).

Tuning Indicator: 0-1 ma front panel meter; rear panel connections to an external oscilloscope are provided.

Mechanical Specifications:

Size:	12 1/8" W x 7 7/8" D x 2 13/16" H 30.8 x 20.0 x 7.1 cm
Weight:	5.75 lbs (2.6 kg), NET 7.00 lbs (3.2 kg), Shipping
Finish:	Two-tone, blue top over beige bottom, matches ST-6000, DS-3000 KSR and other current HAL Products.
Power Requirements:	105-125 VAC (210-250 VAC optional), 50-60 Hz, 15 Watts

3. INSTALLATION

3.1 Initial Inspection

Upon receipt of the ST-5000, unpack and inspect it carefully for shipping damage. If evidence of shipping damage is found, contact the carrier immediately. Before discarding the packing material, check that all parts and accessories are accounted for. If any are missing, please notify the factory or distributor in writing so that replacements can be supplied. The following parts and accessories are furnished with the ST-5000.

Accessory parts:

- 1 - Non-captive AC power cord
- 1 - 6 ft. Audio cable, phono connectors each end
- 4 - 3 pin female connector shells (03-09-2031)
- 2 - 6 pin female connector shells (03-09-2061)
- 24 - male cable pins (02-09-2143)
- 2 - 0.5 ampere, slow-blow fuses
- 6 ft - 2-conductor shielded cable

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*****
**
** CAUTION! A SERIOUS SHOCK HAZARD MAY EXIST WHEN CONNECTING THE
** ST-5000 TO OTHER EQUIPMENT. BEFORE MAKING ANY CON-
** NECTIONS, BE SURE TO DISCONNECT THE ST-5000 AND OTHER
** EQUIPMENT FROM THE AC POWER LINE.
**
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*****
```

3.2 Audio Connections

Audio tones from the receiver as well as ST-5000 tones to the transmitter are both connected via the three pin AUDIO jack on the rear panel. It is highly recommended that the ST-5000 input be connected to a 500 ohm audio output from the receiver. Although the demodulator will work when driven from a lower impedance source (4-8 ohms, for instance), the voltage level from most receivers is insufficient to take full advantage of the wide dynamic range of the ST-5000 input circuitry. Use of a 4 ohm output instead of a 500 ohm output causes a loss of 22 dB in the audio signal strength, which may impair the weak signal capabilities of the RTTY receiving system. If the receiver does not have a 500 ohm output, a 4 to 500 ohm transformer is highly recommended.

The tone keyer output is also connected to the AUDIO connector. This output has a nominal source impedance of 600 ohms, but may be used to drive high impedance audio circuits as well. The output level of the tones is adjustable over the range of 0 to -40 dBm (1.0 V to 10 mV rms) as is described later in section 4.7.

Connections between the receiver and transmitter and ST-5000 can be made using the 6 ft. phono cable supplied. Cut the cable in half; connect one section between pins 1 and 2 (shield) for the receiver audio connection. Connect the other half between pins 3 and 2 (shield) for the transmitter audio input connection. Preparation of the plastic connector and pins is illustrated in Figure 3.1; connections to the AUDIO connector are shown in Figure 3.2.

3.3 Loop Connections

The station RTTY equipment can be connected to the ST-5000 internal loop circuit through pins 1 (+) and 4 (-) of the I/O - CONTROL rear panel connector. The internal loop supply generates a 60 ma dc current flow for mark condition from a 175 volt dc power supply. If a polarity sensitive device such as a solid state keyboard or display generator is connected in the loop circuit, be sure to observe proper polarity connections. Preparation of the plastic connector and pins is shown in Figure 3.1; some common loop connections are shown in Figure 3.3.

C A U T I O N

THE 175 VOLT LOOP POWER SUPPLY CAN CAUSE A LETHAL ELECTRICAL SHOCK IF CONTACTED. BE EXTREMELY CAREFUL WHEN CONNECTING EQUIPMENT IN THE LOOP CIRCUIT TO BE SURE THAT POWER TO THE ST-5000 IS DISCONNECTED. BE SURE TO GROUND THE CABINTRY OF ALL EQUIPMENT CONNECTED IN THE LOOP CIRCUIT AND PROVIDE PROTECTIVE INSULATION FOR ALL LOOP CONNECTION POINTS.

3.4 FSK Connections

A low-voltage data output is also available on the I/O - CONTROL connector at pin 3, labeled "FSK." This signal is derived from the loop circuit and will provide approximately -15 volts on mark condition and +15 volts on space condition. This signal is compatible with a RS-232C data standard and can be used to directly drive solid state display systems such as the HAL RVD-1005 or the DS-3000 KSR units. This signal can also be used to drive saturated diode FSK keying circuits. Preparation of the connector is shown in Figure 3.1 and typical FSK connections are shown in Figure 3.4.

3.5 STANDBY Connections

As explained in section 4.5 , the ST-5000 can be locked into a mark-hold condition where the loop (and FSK) data outputs do NOT respond to an audio input signal. This feature allows "local loop" operations such as preparing tape and transmitting while still using the loop supply of the ST-5000. This mode can be activated by either using the LOCAL position of the front panel LINE switch or by grounding the STANDBY pin (no. 2) of the I/O - CONTROL rear panel connector. The REMOTE feature is generally connected to a pole of the transmit-receive switch or relay so that the demodulator is disabled while transmitting. As before, refer to Figure 3.1 when preparing the connector pins.

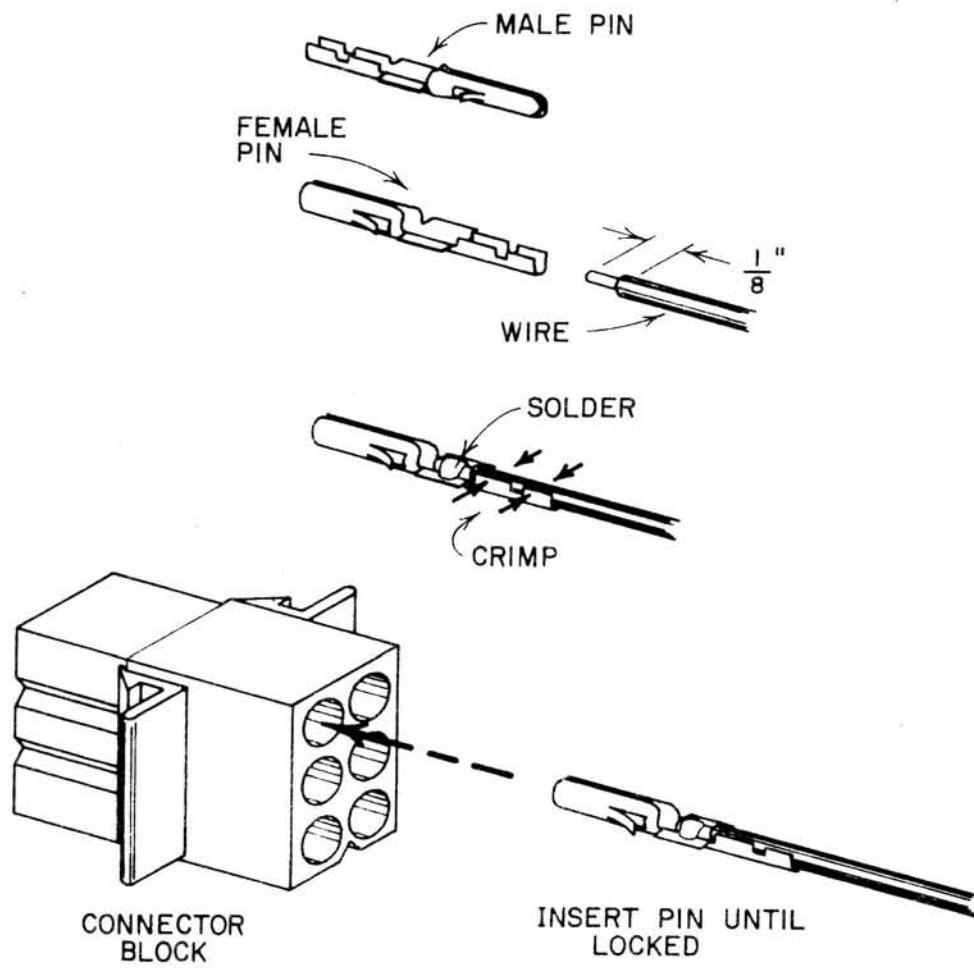
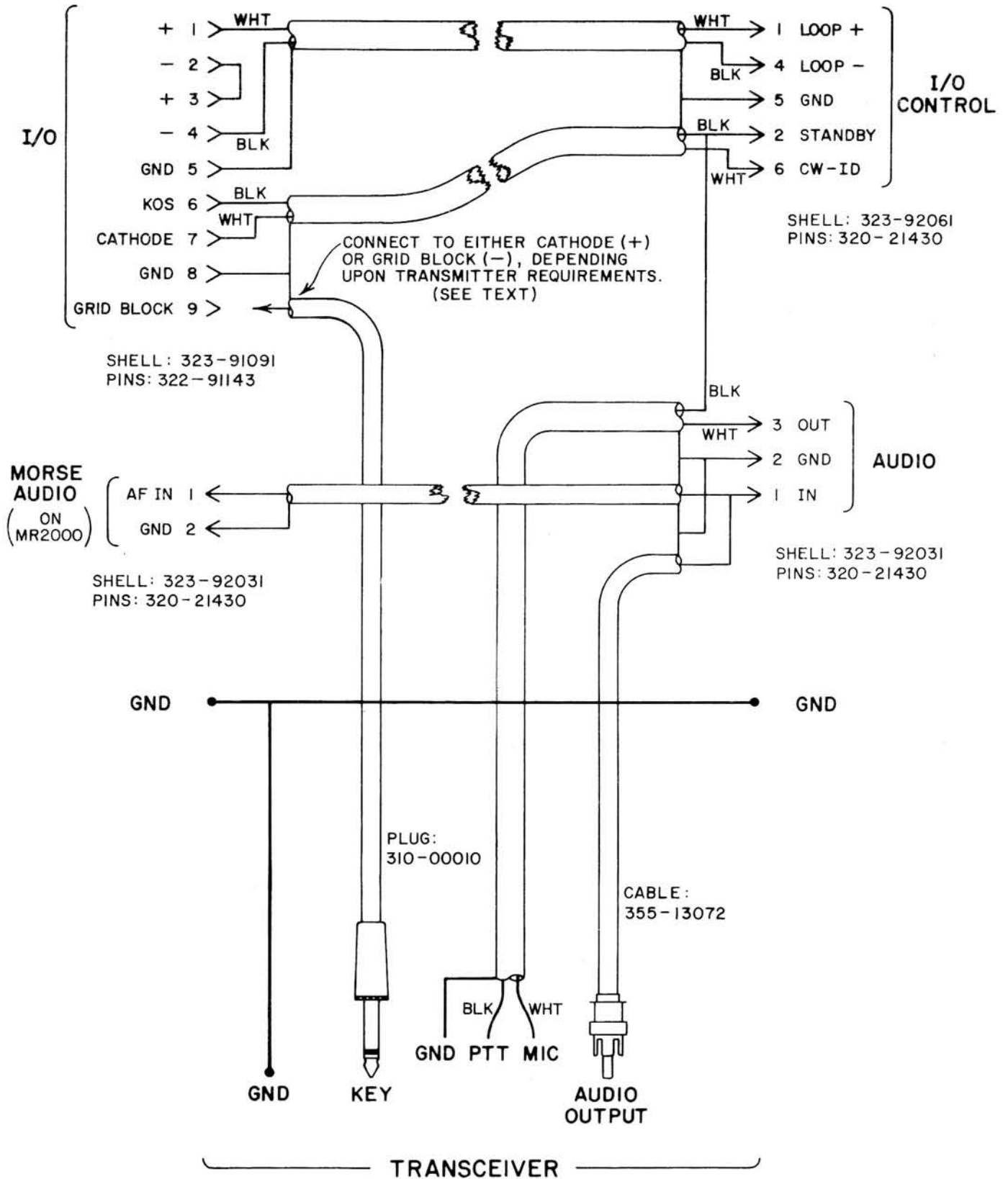


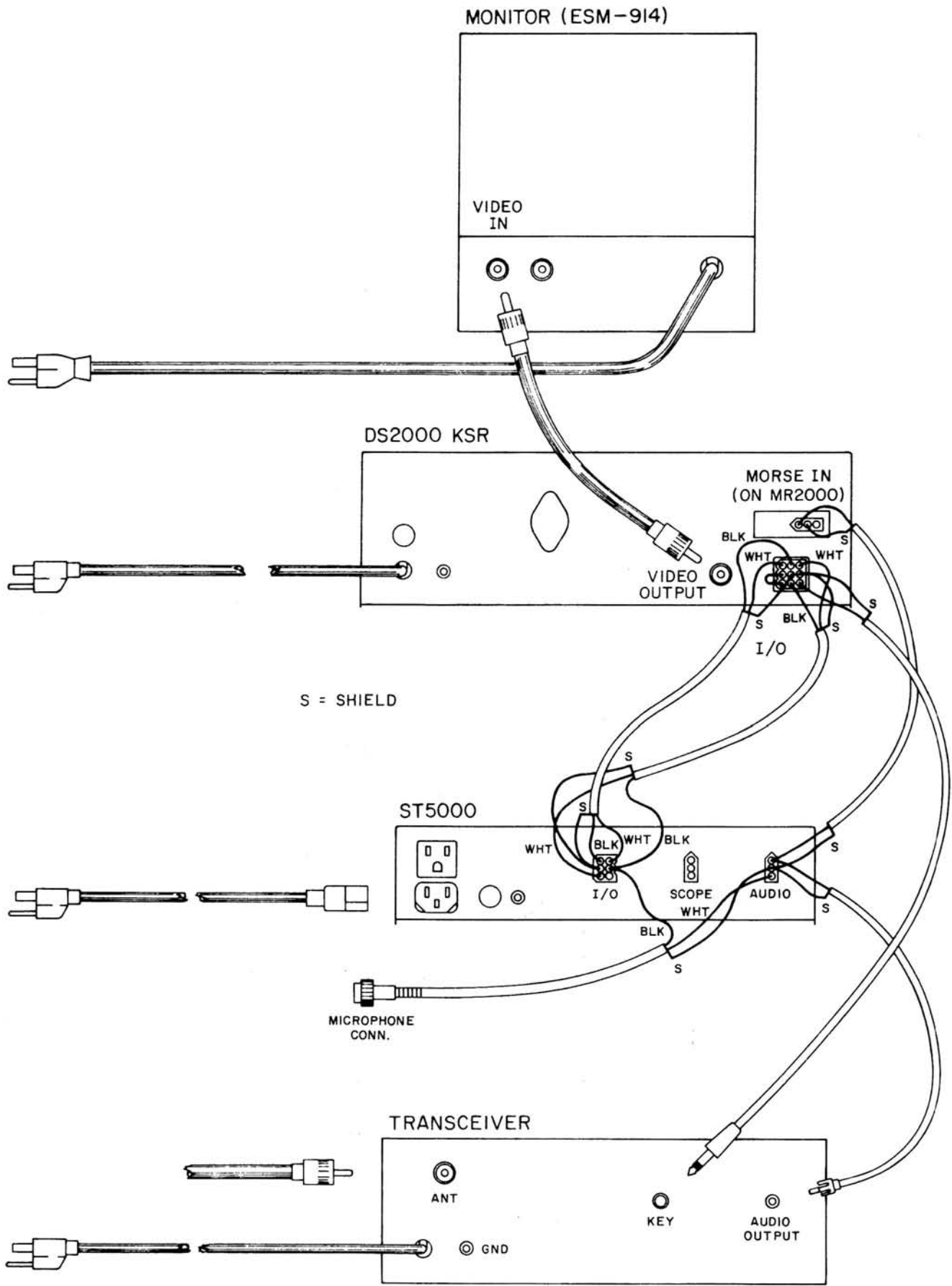
Figure 3.1 Connector Preparation

DS2000 KSR

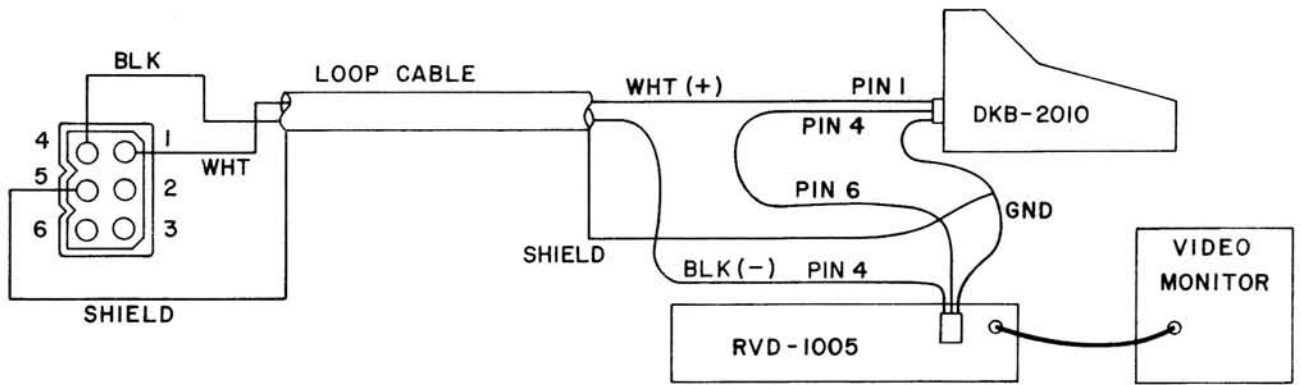
ST5000



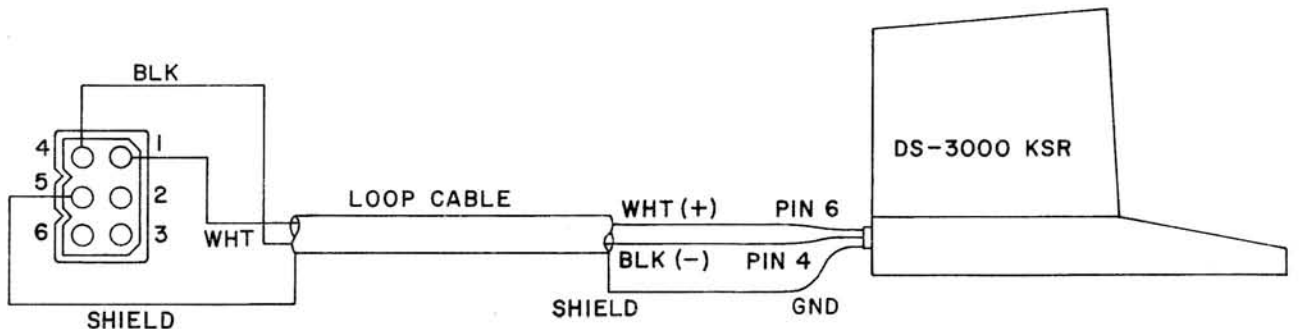
DS2000 and ST5000 System Connection Schematic



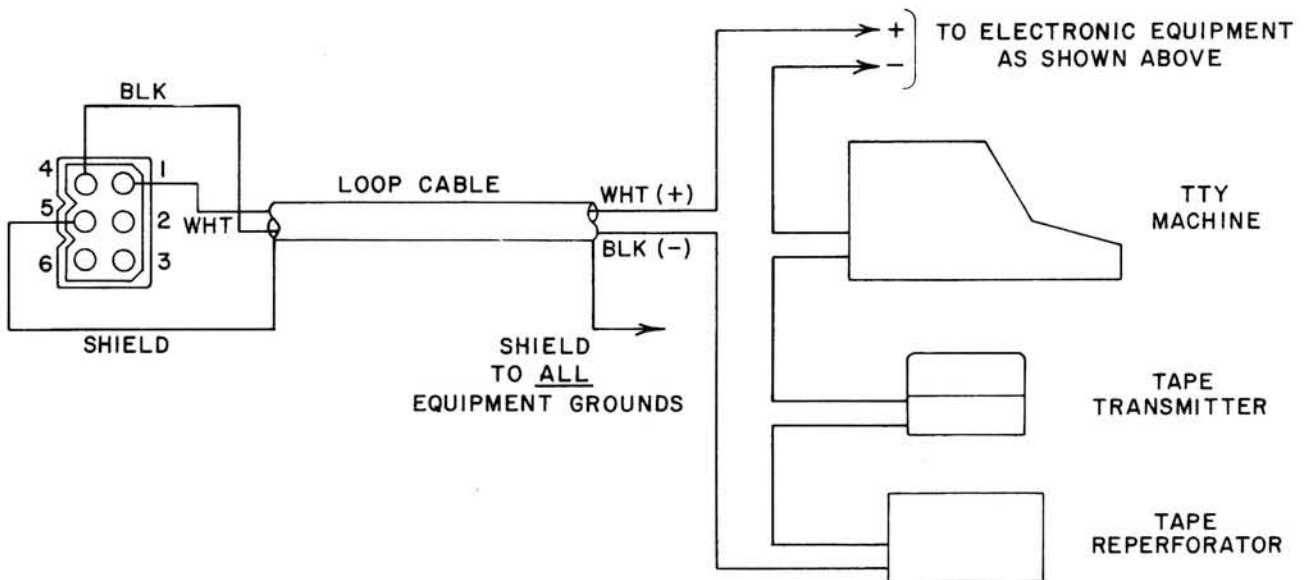
DS2000 and ST5000 System Connection Pictorial



LOOP CONNECTION OF DKB-2010 AND RVD-1005

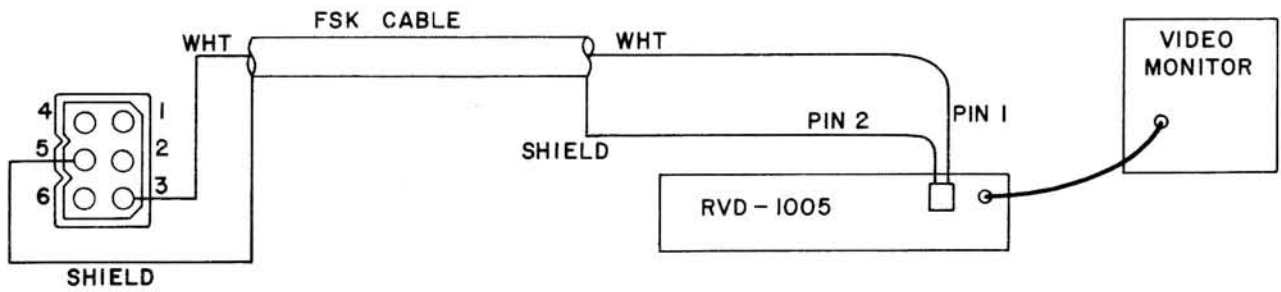


LOOP CONNECTION OF DS-3000 KSR

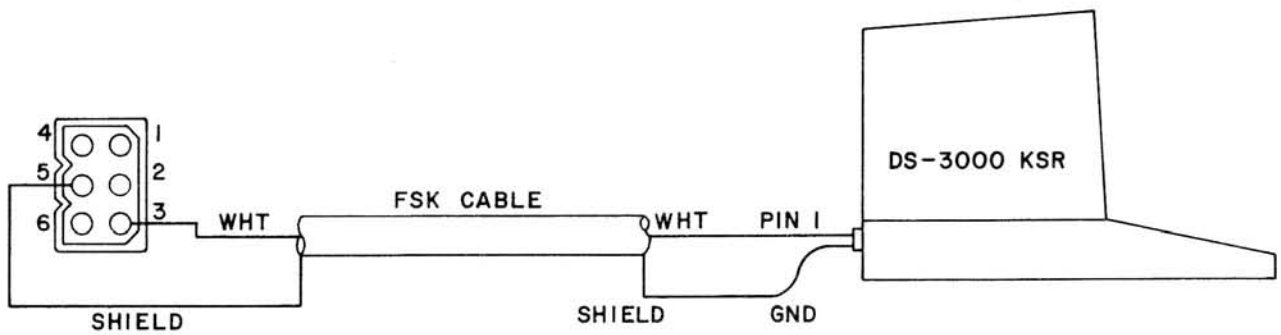


LOOP CONNECTION OF ELECTRONIC AND MECHANICAL EQUIPMENT

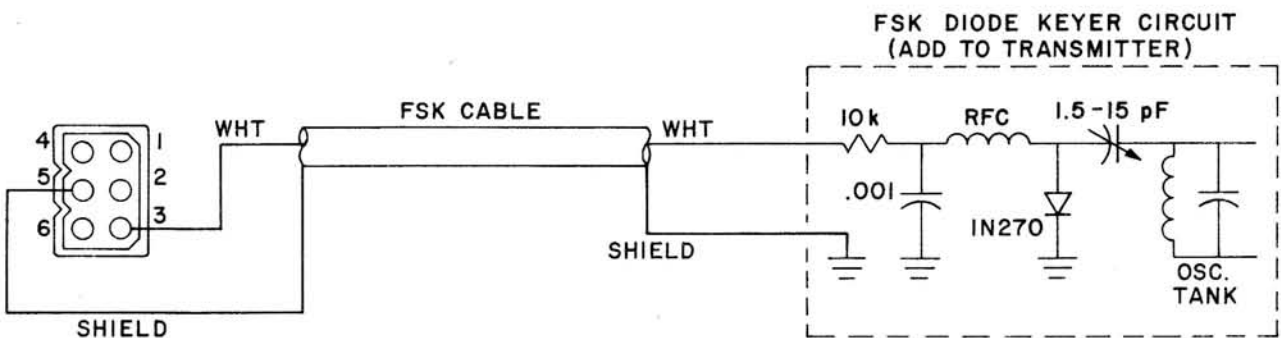
Figure 3.2 Loop Connections to the ST-5000



USE OF FSK OUTPUT TO DRIVE THE RVD-1005



USE OF FSK OUTPUT TO DRIVE THE DS-3000 KSR



USE OF FSK OUTPUT TO DRIVE DIODE FSK CIRCUIT

Figure 3.3 FSK Connections to the ST-5000

3.6 CW ID Key Cable Connection

Pin 6 of the I/O - CONTROL connector is labeled "CW-ID." Connect the station Morse code hand key or electronic keyer between this pin and ground (pin 5) to provide narrow-shift CW identification of the transmitted signal. When an electronic keyer is used, the output circuit for cathode keying should be used, instead of the grid-block keying circuit. In no case should the keyer reflect any negative voltage or positive voltages greater than +12 to the ST-5000.

3.7 AC Power Cord Connection

The ST-5000 can be internally connected to operate from power sources in two voltage ranges: 105 to 125 VAC or 210 to 250 VAC, 50 or 60 Hz. The rear panel power cord connector is of the "universal" USA/European type and mating power cords can be obtained for most common wall connectors. The ST-5000 is normally factory wired for operation from 105 to 125 VAC, 50 to 60 Hz power lines. Upon request at the time of the order, the ST-5000 can also be supplied for 210 to 250 VAC, 50 to 60 Hz operation. When the 210 to 250 VAC connection is supplied, it is indicated by a small tag on the rear panel of the ST-5000. If this tag is NOT on the rear panel, do NOT connect the ST-5000 to a 240 volt line without first checking the internal wiring of the power transformer. Particular attention should be given to the precautionary notes of section 3.8 when connecting to the MOTOR receptacle.

3.8 Motor Power Connection

The power for the teleprinter motor can be supplied by the MOTOR connector of the ST-5000. The power to this connector is controlled by the autostart relay. The TOTAL current supplied by this receptacle should not exceed 10.0 amperes. The following precautions should be observed when using the MOTOR receptacle:

1. The power to the MOTOR receptacle is NOT fused in the ST-5000. The user should be sure that any device attached to this connector has its own fuse protection.
2. The AC voltage furnished on the MOTOR receptacle is the SAME as the AC power line voltage supplied to the ST-5000; if the ST-5000 is operated from a nominal 240 VAC power line, the MOTOR receptacle also furnishes 240 VAC.

The proper power transformer primary connections are:

- 105 to 125 VAC, 50/60 Hz: jumper terminal 1 to 3 and 2 to 4, connect power line to terminals 1 and 4.
- 210 to 250 VAC, 50/60 Hz: jumper terminal 3 to 2, connect power line to terminals 1 and 4.

3.9 Ground Connection

The ST-5000 cabinet should ALWAYS be connected to an adequate ground system. A three-prong grounding type AC power plug is furnished for connection to a grounded-outlet power system (105-125VAC connection). If the wiring of the building is correct, use of the grounding AC plug should provide an adequate SAFETY ground return for the instrument. However, it is a good idea to first check the outlet wiring with a multimeter before plugging in the unit. If a three-prong AC outlet is not available, use a three to two-prong adapter at the wall socket and connect a separate ground lead between the adapter ground lead or ST-5000 cabinet and a good ground. When using 210 to 250 VAC power mains, be sure to connect the cabinet to a good safety ground. OPERATION OF THIS EQUIPMENT WITHOUT AN ADEQUATE SAFETY GROUND INVALIDATES THE WARRANTY.

When the ST-5000 is used in a radio communications system that includes a high-powered transmitter, a short length of low-inductance wire ($\frac{1}{4}$ " wide shield braid is recommended) should be used to interconnect all equipment cabinets, including the ST-5000 and all teleprinters, etc. Lack of a good RF ground connection may cause false triggering of the logic in the control sections or other improper operations. Open-wire antenna feedline systems with high standing-wave-ratios can be particularly troublesome to solid state equipment. In such cases, changing the antenna, matching system, and/or feedline to a matched coaxial line system will usually clear-up RF interference. When good RF grounds and low SWR feed-lines are used, the ST-5000 will work with even very high powered transmitter systems.

Obviously, a great many other I/O and control connections can be made. The user should thoroughly study section 5 and understand how the various sections of the ST-5000 operate and interact before these connections are made.

3.10 External Oscilloscope Connections

The MARK and SPACE AC signals from the discriminator filters are available on the rear panel SCOPE connector. The signals are approximately 2.0 volts peak-to-peak amplitude into a recommended 100 k ohm minimum load impedance. The MARK signal is available on pin 3, the SPACE on pin 1, and signal ground on pin 2.

4. OPERATION

The ST-5000 contains many advanced features designed to assure convenient operation. The operating instructions presented in this section will help you to take full advantage of the demodulator's capabilities. Please read all sections carefully.

4.1 Front Panel Controls and Indicators

The ST-5000 front panel has a total of five push-button switches that allow operator control of the demodulator. Normal operation of the demodulator with ALL automatic features active is obtained by depressing the four right-hand switches and selecting the desired shift with the far-left switch. These functions will be discussed in greater detail later in this section and in section 5. Table 4.1 describes the front panel switches.

Table 4.1 ST-5000 Front Panel Controls

SWITCH	POSITION	FUNCTION
POWER	ON - OFF	Controls AC power to ST-5000
PRINT	LINE	Allows received data to drive printer
	LOCAL	Locks printer in mark for "local-loop" operation
AUTOSTART	ON - OFF	Turns autostart circuit on or off
SENSE	NORM	Normal signal polarity; mark = lower tone
	REV	Reverse signal polarity; mark = higher tone
SHIFT	NARROW	Selects 170 Hz shift
	WIDE	Selects 850 Hz shift

The rear panel connectors have been discussed in detail in section 3 and internal adjustments will be discussed in detail later in this manual.

4.2 Simplified Operation Procedure

The following procedure is suggested for those operators who are anxious to try the ST-5000 without reading the rest of this manual.

1. Prepare audio input and printer cables as described in sections 3.2 & 3.3 and connect the unit to a receiver and printer or display. Do NOT connect a transmitter without reading the rest of section 4 of this manual.

2. AFTER CONNECTIONS ARE MADE, plug-in the ST-5000 and other equipment and turn on the AC power to each.
3. Set the ST-5000 switches as follows:
 - POWER - ON
 - PRINT - LINE
 - AUTOSTART - OFF
 - SENSE - NORM
 - SHIFT - select desired shift
4. Set the receiver to LSB mode and tune to a FSK RTTY signal. (Approximately 3600 kHz at night and 14,100 kHz during the day are good frequencies to look for 170 Hz shift radio amateur RTTY signals at 60 WPM).
5. Tune the receiver dial until the tuning meter deflects up-scale to approximately 0.6 to 0.7 and has minimum fluxuation as the signal changes from mark-to-space. (If an oscilloscope is connected, tune for perpendicular ellipses on the screen).
6. The printer should now print the received signal. If it doesn't, try reversing the SENSE switch or selecting different speeds on the printer or display.
7. NOW, read the rest of this manual!

4.3 Reception of Radio Teleprinter Signals

Radio teleprinter signals are usually generated in two forms: direct shifting of the transmitter carrier frequency by the mark and space teleprinter data (called "FSK") or by shifting the frequency of audio tones with the data and using the audio tones as modulation in either an AM or FM transmitter (called "AFSK"). FSK transmissions are usually used in the HF frequency range, below 30 MHz and AFSK is the normal technique for VHF transmissions, above 30 MHz. A currently popular method used to transmit FSK signals is to apply the frequency-shifted tones as modulation to a single side-band (SSB) transmitter. Since a properly adjusted SSB transmitter signal is the same as that by direct FSK, a separate RF frequency for mark and space data conditions. Reception of such signals is therefore exactly the same as if direct FSK had been used. Use of this technique will be discussed in greater detail in section 4.8.

4.3.1 Receiver for FSK Reception

The performance of the ST-5000 depends to a great extent upon the characteristics of the receiver used and the care taken in tuning the FSK signal. Obviously, the better suited the receiver, the better the quality of the printed displayed output. Some of the desirable receiver characteristics and features are:

1. The receiver should preferably be of the SSB type with selectable sideband. Standard convention is to use LSB mode for FSK reception.

2. The frequency stability of the receiver should be very good - a small amount of drift when receiving a 170 Hz shift signal can cause poor print from even very strong signals.
3. The tuning ratio of the main tuning knob should be slow to allow precise adjustment of the FSK signal into the receiver.
4. The selectivity of the receiver should be slightly greater than the shift to be received: for 850 Hz shift, a bandwidth of 1200 to 2100 Hz is adequate; for 170 Hz shift, a bandwidth as narrow as 400 Hz can be used. Two limitations should be kept in mind, however; the narrower the bandwidth, the greater the frequency stability requirements on the receiver, and wider bandwidths permit more interference and noise to be processed with the FSK signal.
5. A "slow" agc with fast attack and slow decay is very desirable when receiving FSK signals.
6. As mentioned in section 3.2, a 500 ohm audio output connection or speaker to 500 ohm transformer are highly recommended for connection to the ST-5000 input.
7. An adjustable BFO frequency or adjustable pass-band tuning are very desirable features for reception of FSK signals.

Proper positioning of the receiver's BFO with respect to the IF pass-band and the FSK signal is particularly important. The standard convention when transmitting HF FSK signals is to transmit mark data at the higher RF frequency and space at the lower. The separate mark and space RF frequencies are both received within the receiver IF pass-band and mixed in the product detector with the BFO to produce audio tone beat signals which then drive the ST-5000. Since the audio filters of the ST-5000 follow the demodulator standard of mark being the lower frequency audio tone, it follows that the BFO of the receiver should be HIGHER in frequency than the FSK signal. However, if the signal is inadvertently tuned-in using USB (upper side-band) mode, the sense can be corrected with the SENSE switch on the ST-5000 front panel.

The receiver BFO frequency positioning also determines the RANGE of audio frequencies that can be detected and used to drive the ST-5000. The normal SSB receiver has generally been designed for optimum performance with voice signals with a typical audio frequency pass-band of 300 to 2400 Hz. However, the so-called "standard" demodulator audio tones have been 2125 Hz for mark with the space tone higher in frequency by the amount of the shift received. For 170 Hz, both the mark (2125 Hz) and space (2295 Hz) tones fall within the 300 Hz to 2400 Hz pass-band, although they are not centered. However, the 850 Hz shift space tone at 2975 Hz is not detected for all but the strongest FSK signals. Obviously, the 850 Hz shift FSK signals are NOT compatible with the usual SSB receiver if the "standard" demodulator tones are used. There are two solutions commonly applied to this problem, both of which are usable with the ST-5000.

One solution is to simply change the receiver BFO frequency so that the audio pass-band of the receiver is changed to, say 1500 Hz to 3600 Hz, which will pass all of the "standard" demodulator tones, centering the pass-band on the 850 Hz shift signal. In this case, the BFO frequency should be changed so that it is FARTHER AWAY FROM THE CENTER OF THE IF PASS-BAND by

approximately 1000 to 1400 Hz. If the receiver BFO is adjustable, this is a simple solution. However, many modern SSB receivers do NOT have adjustable BFO's; rather, the BFO may be crystal controlled. In such cases, the BFO crystal should be changed for one of the correct frequency as determined above. Alternately, the second solution, outlined below, may be used.

The receiver audio pass-band problem can also be solved by changing the tones used by the demodulator for detection of mark and space. This technique, commonly referred to as "low-tones" allows direct use of a voice SSB receiver with no internal modifications to the receiver. The ST-5000 can be furnished with filters designed to accept a mark frequency of 1275 Hz and therefore space frequencies of: 1445 Hz (170 Hz shift) or 2125 Hz (850 Hz shift). In some cases, this can be the best solution. However, as discussed in the next section, it can lead to a basic incompatibility when receiving AFSK VHF signals as well as presenting some transmitter problems. The ST-5000 can also be adjusted for special sets of input tones between 1200 and 3000 Hz on special order.

4.3.2 Receiver for AFSK Reception

The receiver requirements for AFSK reception are not as exacting as those for FSK reception. Since the teleprinter data is an AFSK modulation of the transmitter, receiver stability is not generally critical. However, since the data is in the form of audio frequency modulation, the frequency of the tones is determined at the transmitter and cannot be changed at the receiver by simply adjusting a BFO or similar control. The current VHF-AFSK standards in use by radio amateurs in the United States use the higher-frequency "standard" tones of 2125 Hz for mark and 2295 or 2975 Hz for space, depending upon the shift used. Therefore, a demodulator with "low-tone" input filters will NOT be compatible with reception of current VHF-AFSK signals. As in the case of the FSK receiver, a 500 ohm audio output is certainly desirable, but may not be as important to performance, particularly if strong-signal VHF-FM signals are used.

4.3.3 Tuning a RTTY Signal

Tuning of the radio receiver for optimum recovery of the teleprinter signal is an operation which may require some practice. Two alternate tuning aids are usable with the ST-5000; the standard tuning meter and a user supplied external tuning oscilloscope. The tuning objective is to adjust the receiver tuning so that the output audio tones match the center frequencies of the ST-5000 filter circuits.

The tuning meter functions in exactly the same manner as that used on the previous HAL models ST-5 and ST-6 demodulators. Portions of the signals from both the mark and space discriminator filters are positive rectified, filtered and summed. The resulting "plus-plus" voltage is used to drive both the tuning meter and the autostart circuit. The amplitude of the "plus-plus" voltage, therefore, depends upon how well the mark or space tones are centered in the discriminator filters. Correct tuning of the receiver is indicated by an up-scale meter deflection that fluctuates very little as the RTTY signal changes between mark and space. The ST-5000 circuits are adjusted so that proper tuning is indicated by a non-varying reading of 0.6 to 0.7 on the meter. Note that the meter may give widely varying readings

when noise, interfering signals, or incorrectly tuned RTTY signals are received. However, it will ONLY give the non-varying, up-scale indication when the RTTY signal is properly tuned.

An external oscilloscope can also be connected to the ST-5000. The oscilloscope presents the standard crossed-ellipse display with the mark signal on the horizontal axis and the space signal on the vertical axis. Because the discriminator filters in the ST-5000 (like those of the ST-5 and ST-6) are relatively broad-band, the mark and space scope displays are NOT lines, but ellipses. The ellipses are fairly narrow when 850 Hz shift is received and wider when 170 Hz is selected. When the RTTY signal is correctly tuned, the ellipses will have maximum length and be essentially perpendicular. The major axis of the ellipse is ALWAYS the parameter to observe and maximize. When the signal is incorrectly tuned, the amplitude of the major axis will be reduced and the two traces may be rotated and/or no longer perpendicular. After using the tuning oscilloscope, the user will discover that, in many cases, the trace positions and amplitudes can be used to determine which direction the receiver dial should be adjusted for correct tuning.

Proper tuning adjustment of the receiver is much more critical when the autostart circuits of the ST-5000 are active than when they are not. This is because the autostart circuitry senses the "plus-plus" voltage which is quite sensitive to the centering of the signals in the discriminator filters. However, if the autostart is not active, the relatively broad bandwidths of the discriminator filters themselves will allow good reception of even poorly tuned RTTY signals. A good operating procedure, then, is to turn the autostart OFF (with the front panel switch) while tuning a signal. When the signal is correctly tuned, the autostart can be activated, if desired. This technique is highly recommended for operators who are unfamiliar with the ST-6 and ST-5000 autostart circuits although, with practice, you may prefer to tune with the autostart circuit on to avoid the garbled print while tuning. Tuning when the autostart is active requires experience and faith in the tuning indicators since there is a delay of 1.5 to 3.5 seconds after correct tuning is achieved before the printer is activated.

The above tuning procedures in general apply only to the reception of FSK RTTY signals. Receiver tuning of AFSK-AM or FM signals will obviously not affect the frequency of the tones. Therefore, tuning of the receiver is not at all critical for AFSK signals. The tuning meter or oscilloscope will indicate the match between the transmitted audio tones and the ST-5000 discriminator filter rather than correct receiver tuning. Obviously, the frequencies of the transmitted tones must match the discriminator filters fairly well for satisfactory autostart operation. Most problems with AFSK autostart systems can be traced to either off-frequency transmitter tones or mis-alignment of the demodulator.

4.4 Use of the SENSE Switch

The SENSE switch allows the ST-5000 to receive signals with either the normal polarity of mark=lower frequency or the reversed sense where mark=higher frequency tone. ALL features of the ST-5000 function equally well for either signal polarity. This reverse position is convenient if the signal has been inadvertently tuned-in using USB rather than LSB receiver

mode. ONLY the discriminator filter frequencies are controlled by this switch; the tone generator sense is NOT switchable.

4.5 Use of the PRINT Switch

There are many occasions in which it is desirable to turn-off the received data to the teleprinter loop circuit and just use the internal loop supply to operate the RTTY machines at the station. Operations such as local testing of equipment or preparation of punched paper tape are typical examples. When the PRINT switch is in LINE position, data from the receiver is allowed to key the loop circuit. When the switch is in LOCAL position, the loop keyer stage is held in mark condition and received data will NOT drive the loop. The demodulator can also be held in LOCAL position by grounding the STANDBY line on pin 2 of the I/O CONTROL connector.

4.6 Use of the Autostart Circuitry

The ST-5000 autostart circuit operates in a manner very similar to that of the ST-6000, ST-5 and earlier TT/L and TT/L-II demodulators. The autostart provides a two-step control of the printer - mark-hold and control of the AC power to the printer motor. The autostart circuit senses the voltage on the "plus-plus" line, which is, as described previously, proportional to the frequency match between the signal tones and the discriminator filters. If both mark and space tones are not sensed in the discriminator, the "plus-plus" voltage remains at a low average value and the autostart circuit will be in the standby condition, giving a continuous mark output. After the autostart has remained in the standby or mark-hold condition for 20 seconds (nominal), the power to the MOTOR AC socket on the rear panel is turned off with an internal relay. If valid mark and space tones are now sensed in the discriminator, the "plus-plus" voltage will increase and activate the autostart after a delay of 3.5 seconds. The AC power to the MOTOR connector is now switched on and the data is allowed to drive the loop. Immediately after the tones turn-off at the end of a transmission, the autostart returns the data to mark hold, completing the cycle.

Because of the turn-on delay inherent in the autostart, it is recommended that tuning of the RTTY signal be done with the AUTOSTART switch in the OFF position during initial testing of the ST-5000. After the operator has some practice in tuning the receiver, he may then wish to leave the autostart circuit ON, remembering to account for the time display of the autostart.

The autostart trigger voltage level on the "plus-plus" line is adjustable with a potentiometer mounted on the control circuit board inside the ST-5000 cabinet. The potentiometer is located almost in the exact middle of the circuit board and can be identified as a 250k pot near the letters "AS" on the circuit board. This control is normally set at the factory to trigger the autostart on all signals giving a tuning meter reading of 0.6 and higher. The user may adjust this control to fit his own requirements. If the autostart sensitivity is set too close to the noise level, false printing may occur on noise or interfering signals; if set to too high a level, the autostart may not trigger on all but the strongest signals with exactly correct shift. Experience will determine the optimum setting for a particular system. Notice that the "plus-plus" voltage and therefore

autostart sensitivity are directly proportional to the degree of match between the signal tone frequencies and the center frequencies of the discriminator filters. It may therefore be difficult to set the autostart sensitivity and receiver tuning to respond to signals with improper frequency shift. Also, if the transmitter OR receiver should drift, the signal tones will soon no longer match the discriminator filters, causing the autostart to "shut-down." If drifting is a problem, the receiver should either be monitored often and manually retuned as required or the autostart should be switched OFF.

4.7 Tone Keyer Circuit

The ST-5000 includes a tone keyer that is very similar in design to the previous HAL model XTK-100 tone keyer board. All mark, space, and CW-ID tones are digitally synthesized from a type 555 IC oscillator. Unlike previous tone keyers, the ST-5000 CW-ID tone is generated at 100 Hz BELOW the mark tone instead of above. This further reduces the chances of falsely triggering the autostart of the receiving demodulator, even when 170 Hz shift is used. The tone keyer is driven from the loop derived FSK output signal. The tone output amplitude can be adjusted over the range of 0 to -40 dBm (approximately 1.0 V to 10 mV across 500 ohms) with an internal potentiometer. The amplitude is adjusted with the "OL" potentiometer, located on the rear of the circuit board. Although the output impedance of the tone keyer is 500 ohms, virtually any load impedance from 500 ohms to several megohms can be driven by the ST-5000. It is NOT necessary to terminate the audio output connector in a 500 ohm load.

4.8 Transmitting Radio Teleprinter Signals

As mentioned previously in section 4.3, radio teleprinter signals are generated by either shifting the transmitter RF frequency with the data (FSK) or by modulating the transmitter carrier with audio tones whose frequencies are shifted by the data (AFSK). Usually, FSK transmission is used for radio frequencies lower than 30 MHz and AFSK above 30 MHz. The ST-5000 can be used to receive AND transmit both FSK and AFSK types of signals.

4.8.1 Transmitting FSK Signals

There are two different techniques that are normally used to generate an FSK teleprinter signal. The simplest method involves direct shifting of the frequency of an oscillator stage in the transmitter. Typically, the data signal is used to turn on or off a diode switching circuit that effectively increases the oscillator tuned circuit capacitance on space, thus lowering the transmitter frequency for space condition of the data. A typical diode keyer circuit is shown in Figure 3.3. Note that the FSK data output is ideally conditioned for this application. Further information on this type of circuit can be found in a current edition of the Radio Amateur's Handbook (AARL, Newington, Conn.) or in the Radio Handbook (Ore, Howard W. Sams, Inc., Indianapolis, Ind.), or other text on radio transmitters. The standard radio amateur polarity convention is to make the mark frequency higher in frequency than the space frequency, although a number of exceptions are to be found, particularly in commercial applications.

A second technique to generate FSK uses a SSB type of radio transmitter. The AFSK tone output from the tone keyer is used as the audio modulation for the transmitter. Since a properly adjusted SSB transmitter suppresses one

sideband and the carrier of the AM signal, the RF output for a single frequency tone input is simply an RF carrier, displaced from the original carrier frequency by the tone frequency. When the tone frequency changes, the RF output frequency also changes by the same amount. Historically, the audio tone standard has been to designate mark as the lower frequency AUDIO tone and space as the higher. Thus, to achieve "normal" FSK RF output with mark as the higher RF frequency, the LSB (lower sideband) mode is used in the SSB transmitter (and receiver as explained in section 4.3). This technique is often mistakenly called the "AFSK-SSB" or simply "AFSK" method. However, the end result is exactly the same as if the transmitter were directly frequency shifted by the data and "FSK" is the true description of the RF signal generated.

At first glance, this SSB method is very attractive; it requires no internal modification to the transmitter and can use readily available SSB transmitters. However, there are a number of precautions that must be traced to the basic fact that SSB transmitters have been specifically designed to transmit voice signals and the performance and specifications are optimized for voice applications. The first conflict in specifications is in the duty-cycle rating of the transmitter. The duty-cycle of the typical voice is at best 50% (less compressors, etc.) while a RTTY transmission has a 100% duty-cycle. SSB transmitter power amplifier stages are usually designed to take advantage of the reduced duty-cycle of a voice signal to produce relatively high output powers in small enclosures with proportionally smaller power supplies. If the same SSB transmitter is operated in RTTY service at full voice ratings, the output amplifier and/or power supply will usually fail. Therefore, the SSB transmitter rating must usually be reduced by at least 50% when 100% duty-cycle RTTY transmission is used. There are a few commercially available SSB transmitters that will accommodate RTTY at full power, usually with the addition of a blower or heavy-duty power supply. The user should carefully check the rating of his SSB transmitter before using it in RTTY service.

Another problem often encountered when the tones are used with a SSB transmitter is very similar to the BFO-passband problem previously discussed in section 4.3.1. Since the SSB transmitter is designed to transmit the voice frequency range of 300 to 2400 Hz, it follows that some of the standard "high-tones" will NOT be transmitted, particularly the 2975 Hz space tone for 850 Hz shift. As with the SSB receiver, there are two ways to solve this problem, shift the carrier oscillator frequency with respect to the filter passband, or use lower frequency tones. The same procedure used to change the receiver BFO frequency can be used to change the transmitter carrier oscillator frequency. This may even be less convenient to do in the transmitter than the receiver since it usually involves changing a crystal in the transmitter. Use of the "low-tone" set of keyer frequency is always the simplest solution. However, use of the "low-tones" should be done with care for the following reasons:

1. SSB transmitters generally have no more than 55 dB of carrier rejection when properly aligned. If the balanced modulator has not been recently re-adjusted, the carrier rejection may well be no more than 25 to 35 dB. Transmission of a small amount of carrier with a SSB voice signal is not usually objectionable. However, when the SSB transmitter is used to transmit RTTY signals, the unpressed carrier is now a spurious emission which is illegal

and may cause receiving problems. In general, the carrier suppression and adjustment stability of a PHASING-TYPE of SSB transmitter is even worse and this type of transmitter should NOT be used to generate RTTY signals.

2. When the "low-tones" are used, the mark frequency is 1275Hz. If there is any distortion in the SSB transmitter audio or modulator, the second harmonic may be generated, causing radiation of still another spurious signal.
3. The present convention for AFSK-VHF transmission of RTTY signals in the United States is to use the "high-tones," 2125 Hz mark and 2295 or 2975 Hz space tones. A demodulator set-up for "low-tones" is NOT compatible with this application.

Conversely, if the transmitter carrier oscillator is shifted so that the standard "high-tones" can be used, the carrier rejection is greatly increased, audio distortion products generated in the transmitter do NOT fall within the transmitter filter passband, and the demodulator is then usable for BOTH FSK and AFSK applications. Note that 170 Hz shift with "high-tones" can be used without changing the transmitter carrier oscillator since both 2125 Hz (mark) and 2295 Hz (space) fall within the voice passband. However, the carrier rejection will be no better than it is for a voice transmission. Alternately, the following points FAVOR the use of the "low-tones:"

1. The current IARU international standards call for use of "low-tones."
2. The "low-tones" have been successfully used in commercial and military applications for some time with satisfactory results.
3. If the precautions noted above regarding carrier rejection and transmitter audio distortion are observed, the total system performance using "low-tones" can be just as satisfactory as a system using "high-tones."

The "optimum" choice between the two tone sets will vary with the application intended and the preferences of the user. It is hoped that the previous discussion will help alleviate some of the confusion that exists concerning the use of "low" vs "high-tones."

4.8.2 Transmitting AFSK Signals

Transmitting AFSK RTTY signals is much simpler than FSK signals. It is usually only necessary to connect the tone keyer output to the transmitter audio input, adjust the tone level, and transmit. Again, however, the duty-cycle rating of the transmitter should be considered. In particular, most VHF-FM transmitters are designed for intermittent duty and may NOT permit extended RTTY transmissions without reducing the transmitter power.

5. ST-5000 CIRCUIT DESCRIPTION

Virtually all of the ST-5000 circuitry is constructed on a single circuit board which is then linked to the cabinet with plug-in connectors for rear panel connections, the motor relay, the loop resistor, and power transformer connections. The circuitry of the ST-5000 is illustrated in the block diagram of Figure 5.1, the schematics of Figures 5.3 and 5.4, and the layout drawings of Figures 5.5 and 5.6. Schematic diagram symbol conventions are shown in Figure 5.2. Refer to these diagrams for the following discussion.

5.1 Input Limiter Stage

The audio input tones from the station receiver are amplified and limited in operational amplifier 11, a type 709 with fast-response compensation. Additionally, two silicon diodes are placed across the input to prevent damage to the demodulator by very high-amplitude audio signals. This stage is similar to that used in both the earlier ST-5 and ST-6 demodulators.

5.2 Discriminator Filters

Separate mark and space discriminator filters are constructed of two high-Q active filters, one filter for each tone. These filters are specifically designed for broad band-width, linear phase response to assure optimum signal recovery in the face of noise as well as to minimize phase distortion of the signal. The mark filter center frequency remains constant for all selected shifts while the space filter center frequency changes with the shift switch. Two type 1458 dual operational amplifiers are used in the discriminator filter; the filters are patterned after those used in the HAL ST-6000 Demodulator.

5.3 Discriminator Detectors

The signals from the mark and space discriminator filters are detected in separate active detector circuits that use another 1458 IC (14). The active detector circuit avoids the normal non-linearities and offset voltages of simple diodes and gives precision rectification of the AC signals over a wide dynamic range of input amplitudes, reducing the distortion on received signals as well as extending the dynamic range of receivable signals. The combination of the high-gain, wide-bandwidth limiter, the broad-bandwidth separate discriminator filters and the active discriminator detector circuits produces exceptional demodulator performance for a wide range of input signal amplitudes and distortion.

5.4 Meter Amplifier and Detectors

A portion of both the mark and space filters are also rectified by IN270 germanium diodes, filtered, and amplified by an emitter-follower (MPS3394). The resulting signal is of positive polarity for both mark and space signals, the amplitude depending upon the frequency match between the input signal and the discriminator filters. This "plus-plus" signal, as in the ST-6 and ST-6000, drives a tuning meter as well as the autostart circuit.

5.5 Active Low-pass Filter

Both sections of a 1458 are used in a three-pole active low-pass filter that follows the discriminator detector stages. The cut-off frequency of this filter is set to approximately 82 Hz to minimize noise on the signal while still allowing use of the ST-5000 at data rates up to 110 baud. This stage is similar in design to that of the ST-6 and ST-6000 demodulators.

5.6 Slicer Amplifier and Keyer Stages

One-half of a 1458 operational amplifier is connected as a high-gain clipping amplifier to produce fast rise-time keying pulses for mark and space conditions. The input of the amplifier can be switched for either inverting or non-inverting operation by the front panel SENSE (NORM - REV) switch, allowing the polarity of mark and space tones to be interchanged. The slicer directly drives a type 2N5655 high-voltage switching transistor which can then be connected to key the 175 VDC loop supply. The input to the 2N5655 can also be placed in a mark-hold condition by signals from either the autostart or standby circuits through the 1N4148 OR-gate diodes.

5.7 Autostart Stage

The "plus-plus" signal is a maximum when BOTH mark and space received tones match the center frequencies of the ST-5000 discriminator filters. This voltage is further integrated or "delayed" and then applied to half of a 1458 amplifier (16) which functions as a threshold detector. When a signal is correctly tuned-in, the "plus-plus" voltage goes to a maximum non-varying condition and gradually charges the electrolytic capacitor at the amplifier input. After 2 to 4 seconds, the threshold of the amplifier is exceeded, causing the output to go negative. This negative signal turns "on" two PNP dc amplifiers (MPS6518's), turning on the motor relay. When the RTTY signal is lost, the "plus-plus" voltage decreases, after 2-4 seconds the output of 16 goes to a plus voltage, putting the keyer stage into mark-hold through the 1N4148 diode. The input to the PNP relay drivers slowly rises as the electrolytic capacitor charges until the drivers turn-off, de-energizing the motor relay after 20 to 40 seconds. The Keyer stage can be put into mark-hold and the motor energized manually through the Remote Standby rear panel connection. Connecting the Remote Standby terminal to ground puts the keyer in mark-hold and turns-on the motor.

5.8 Tone Keyer Stages

The AFSK tones of the ST-5000 originate in a type 555 IC oscillator (17). The oscillator frequency (8 times the output frequency) is controlled by the 2700 pf silvered mica capacitor and the selected charging resistor. Types MPS3394 and MPS6518 transistors provide resistor switching for space or CW-ID data conditions. Different space resistor chains are selected by the front panel SHIFT switch to allow separate adjustment of each tone. As in the ST-6000, the CW-ID shift feature of the ST-5000 shifts the mark tone DOWN, rather than up, thus preventing false triggering of autostart circuits, especially with 170 Hz shift.

The pulse output of the 555 drives the 4024 counter (18) whose outputs are combined in exclusive-OR gate 19 (4030) to synthesize an 8-step sinewave approximation. A type 1458 (110) is then used as an active low-pass filter

to remove the harmonic components of the synthesized signal. The other half of 110 serves as an output amplifier stage. The gain of the amplifier is adjustable (OL=Output Level) to allow output amplitude adjustment over the range of -40 to 0 dBm.

5.9 Power Supply

The ST-5000 uses IC voltage regulators (I11 and I12) to produce the +12 and -12 volt supplies required for the operational amplifiers. A separate 175 volt, 60ma loop power supply is part of the ST-5000 demodulator. A voltage that varies from negative on space to positive on mark is derived from the loop supply with resistor dividers. This "FSK" voltage is controlled by the loop current and drives the AFSK tone generator and can be connected via the rear panel connector for a variety of applications as explained in section 3.4. Unloaded, the "FSK" signal may swing from -15 volts on mark to +15 volts on space; with loading, the voltage swing will be reduced.

The ST-5000 power transformer can be connected for either nominal 120 or 240 VAC, 50/60 Hz power line voltages. The 120 VAC connection is shown in Figure 5.4. To change a unit from 120 to 240 VAC operation, remove the jumpers from between transformer pins 1 and 3 as well as from between pins 2 and 4; add a jumper between pins 2 and 3. Do not change the other connections to the transformer. Note that the MOTOR accessory socket will provide the same voltage as that of the input power line.

5.10 User Adjustments

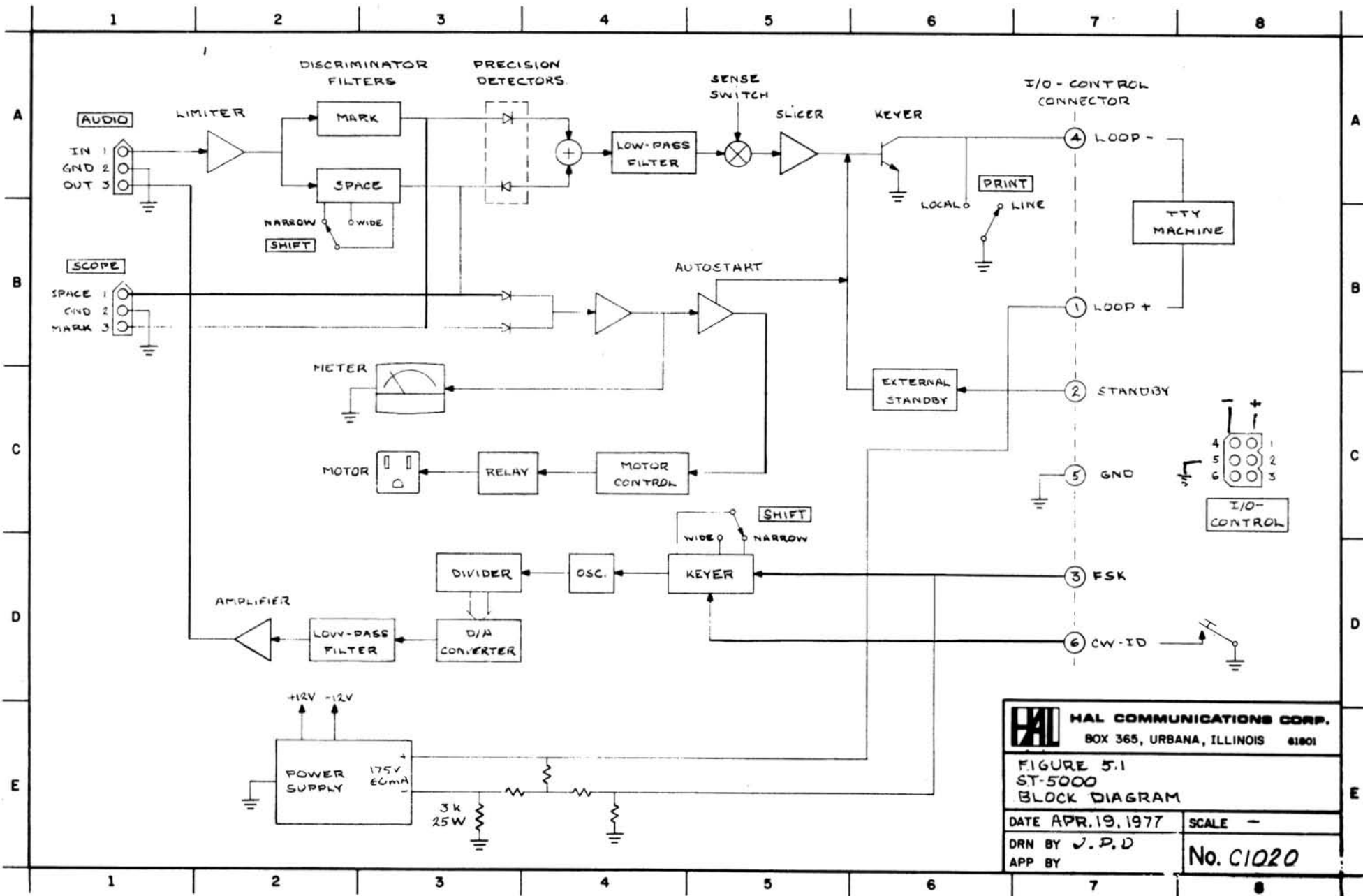
There are a total of eleven trimming potentiometers on the ST-5000 circuit board, most of which are factory adjusted and should NOT require further alignment. All controls are shown and labeled on the schematic and layout diagrams; the circuit board is likewise labeled with a two-letter abbreviation of the function name; for example, MS for Meter Sensitivity, AS for Autostart Sensitivity, and OL for Output Level. In general operation it should not be necessary to adjust any controls except these three - complete realignment should be performed by authorized personnel.

To set the Meter Sensitivity (MS control), tune a station in for a maximum meter deflection on the mark tone (1275 or 2125 Hz). Now adjust the MS control for a meter reading of 0.7 ma. Retuning the signal for space tone should again cause a meter deflection of 0.7 ma.

The Autostart Sensitivity (AS control) is set by first setting the MS control on the mark tone as described above and then detuning the receiver so that the meter deflection decreases to 0.6 ma. Control AS is now set so that the autostart just trips, indicated by monitoring the voltage output on pin 1 of 16 (test point E). The test point E will change from a high positive voltage (approximately +10 volts) to a similar negative voltage (-10 V) when the autostart activates. Either a zero-center voltmeter or dc oscilloscope can be used to monitor the test point.

The Output level (OL control) of the AFSK generator section should be set to produce the desired amount of modulation in the transmitter. If the desired setting of the control occurs at the lower end of the rotation, it is probably a good idea to use two resistors to make a 5 or 10:1 voltage divider of the AFSK output and then increase the control setting to compensate.

The other controls should not generally require alignment. It is particularly recommended that controls SB (Space Balance), WR (Wide Receive), NR (Narrow Receive), and MR (Mark Receive) not be adjusted since they are interacting adjustments that affect the discriminator filter adjustment. Control LB (Limiter Balance) adjusts the output of I1 (test point A) for zero volts dc with no input signal; controls MT (Mark Transmit), NT (Narrow Transmit), and WT (Wide Transmit) allow adjustment of the AFSK tone frequencies. Using a counter, adjust the mark tone first.



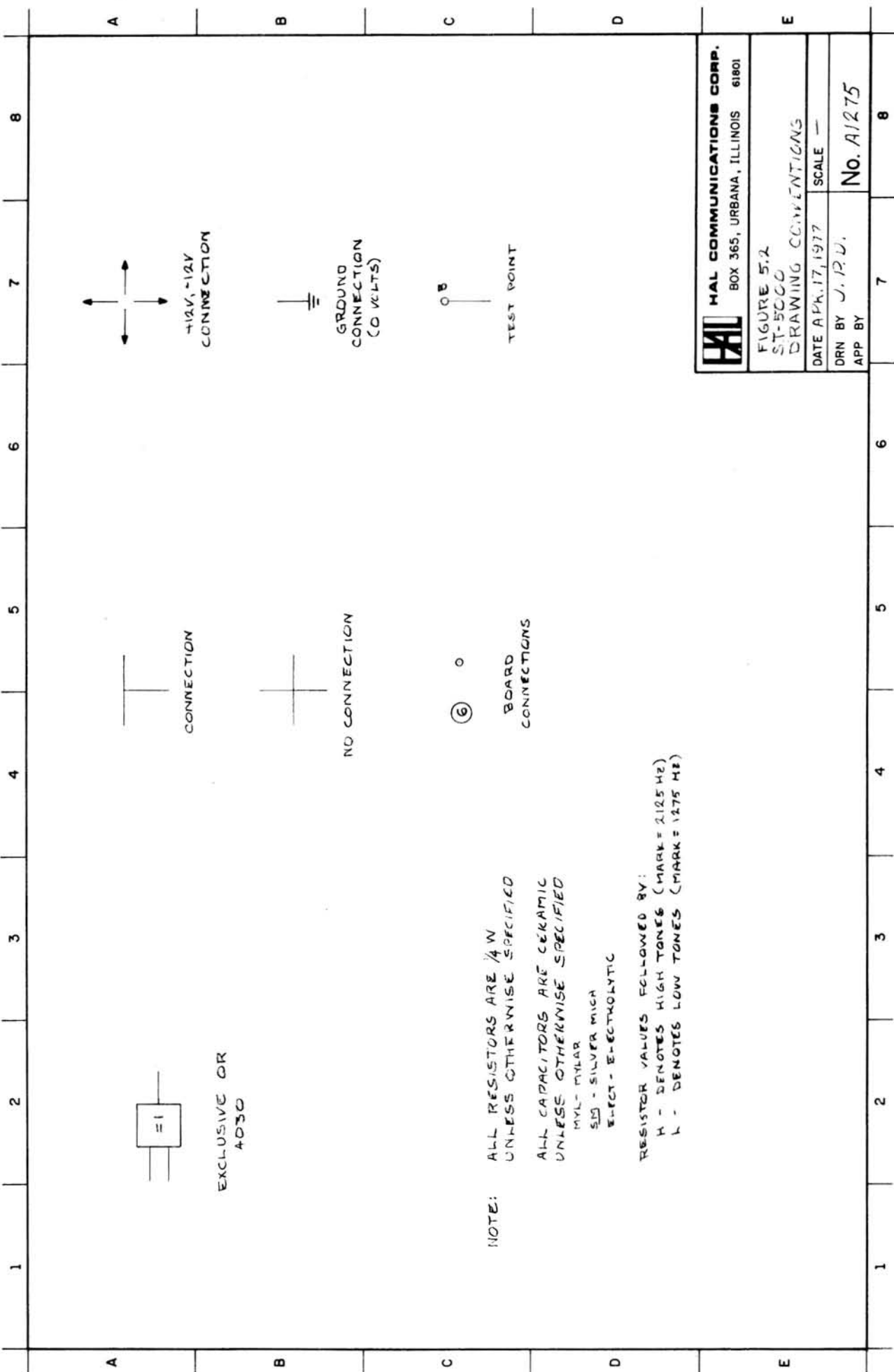
HAL COMMUNICATIONS CORP.
 BOX 365, URBANA, ILLINOIS 61801

FIGURE 5.1
ST-5000
BLOCK DIAGRAM

DATE APR. 19, 1977 SCALE -

DRN BY J. P. D. APP BY

No. C1020



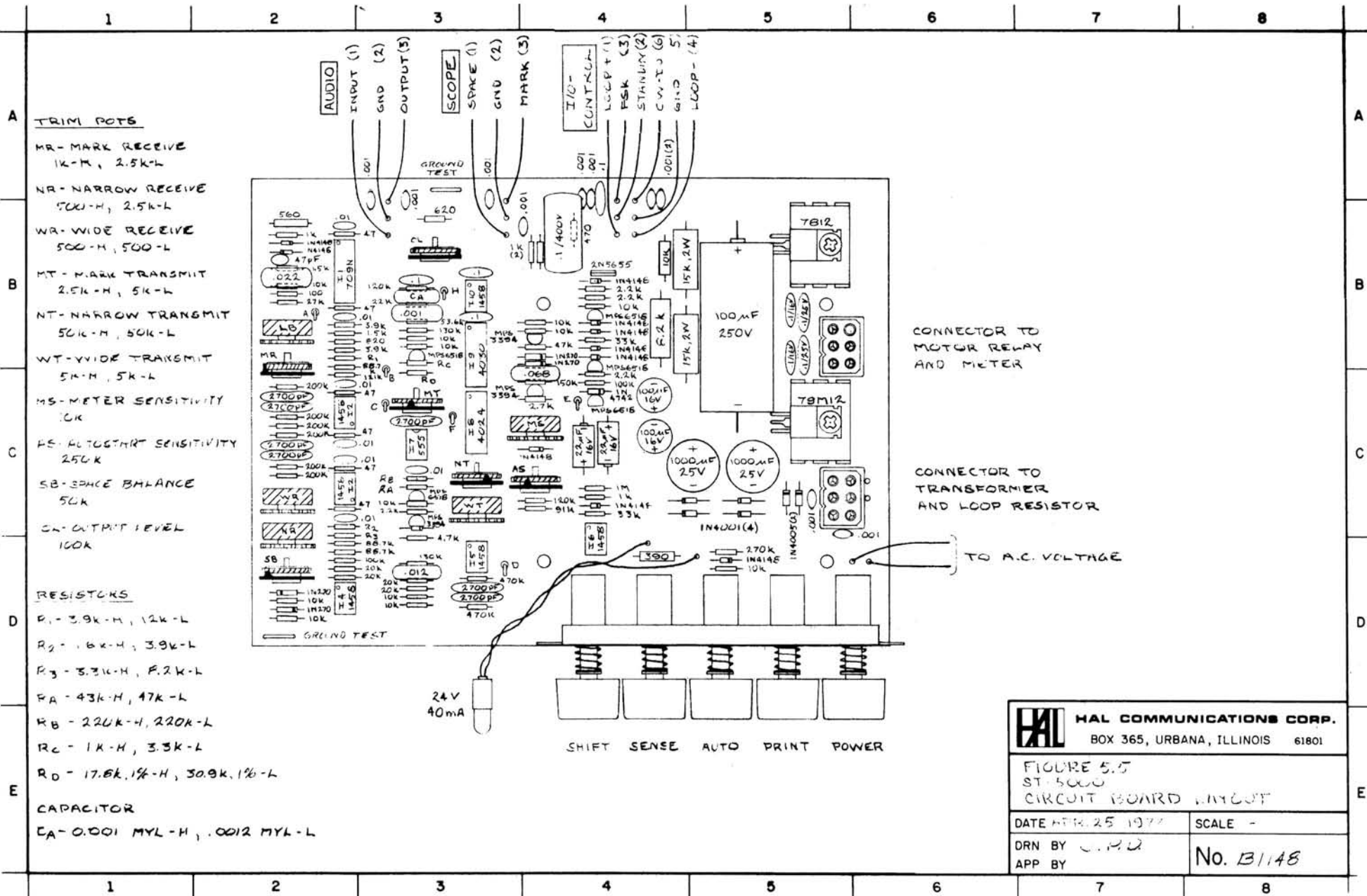
NOTE: ALL RESISTORS ARE 1/4 W
UNLESS OTHERWISE SPECIFIED

ALL CAPACITORS ARE CERAMIC
UNLESS OTHERWISE SPECIFIED

MYL - MYLAR
SIL - SILVER MICA
E-ECT - ELECTROLYTIC

RESISTOR VALUES FOLLOWED BY:
H - DENOTES HIGH TONES (MARK = 2125 HZ)
L - DENOTES LOW TONES (MARK = 1275 HZ)

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	FIGURE 5.2 ST-5000 DRAWING CONVENTIONS	
DATE APR. 17, 1977		SCALE -
DRN BY J. P. D.		APP BY
		No. A1275

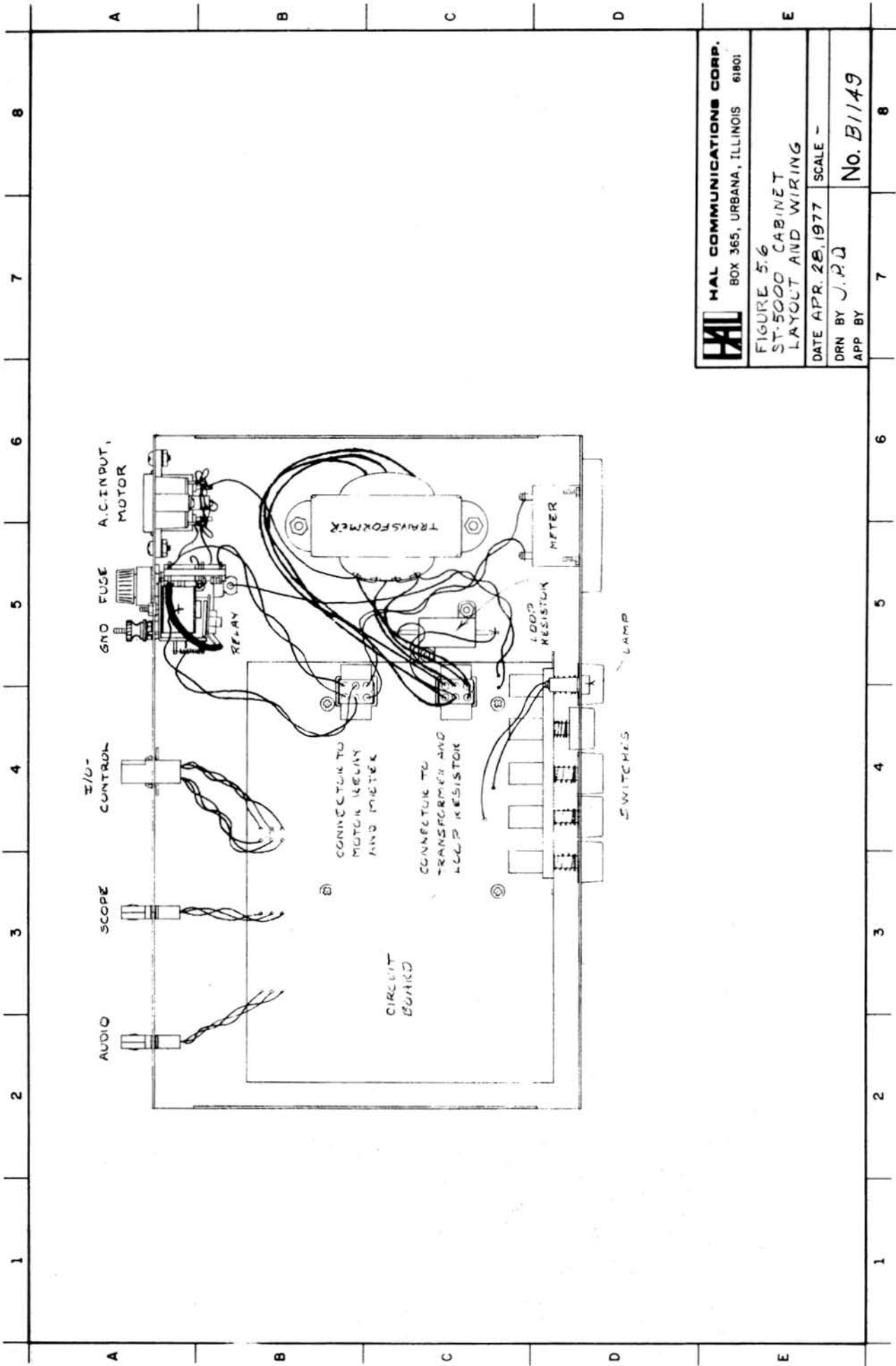


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FIGURE 5.5
ST-5000
CIRCUIT BOARD LAYOUT

DATE APR 25 1977 SCALE -

DRN BY J.P.D. APP BY No. B1148



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FIGURE 5.6
 ST-5000 CABINET
 LAYOUT AND WIRING

DATE APR. 28, 1977 SCALE -

DRN BY J.P.D.
 APP BY

No. B1149

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LIMITED WARRANTY

HAL Communications Corp. of Urbana, Illinois, hereby warrants to the original purchaser only that any new equipment manufactured by HAL Communications Corp. shall be free from defects in materials and workmanship for a period of one year from the date of original purchase. In the case of parts kits, this warranty applies only to materials and not to workmanship in kit assembly.

In the event of a defect in materials or workmanship during the warranty period, HAL Communications Corp. will, at its own expense, repair the defective unit and replace any defective parts. Costs of shipping the unit to HAL Communications Corp. shall be paid by the purchaser, as well as costs of removal and reinstallation of the unit. HAL Communications Corp. will bear the shipping costs incurred in returning the unit to the purchaser.

To obtain service under this warranty, the original purchaser should do the following:

1. Notify, as soon as possible, the Customer Service Department at HAL Communications Corp., Urbana, Illinois, either in writing or by telephone, of the existence of a possible defect;
2. At the time of notification, identify the model or serial number, the approximate date of purchase, the place of purchase, and the possible defect;
3. Hold the unit until a written return authorization is received.
4. Return the unit, freight prepaid, upon the receipt of the written return authorization.

Correct installation, use, maintenance, and repair are essential for proper performance of this product. The purchaser should carefully read the technical manual.

This warranty does not apply to any defect which HAL Communications Corp. determines is due to any of the following:

1. Improper maintenance or repair, including the installation of parts or accessories that do not conform to the quality and specifications of the original parts;
2. Misuse, abuse, neglect, improper installation, or improper operation (including operation without a proper safety ground connection);
3. Accidental or intentional damage.

All implied warranties, if any, are limited in duration to a period of one year from the date of original purchase. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you.

HAL Communications Corp. disclaims any liability for incidental or consequential damages arising out of the use of, or inability to use, this product. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

