TECHNICAL MANUAL

OPERATOR'S, ORGANIZATIONAL,

DIRECT SUPPORT AND GENERAL SUPPORT

MAINTENANCE MANUAL

FOR

PHASE JITTER METER

M E.490/U

(HEKIMIAN MODEL 48)

(NSN 6625-01 005-7226)

HEADQUARTERS, DEPARTMENT OF THE ARMY

APRIL 1981

5 SAFETY STEPS TO FOLLOW IF SOMEONE IS THE VICTIM OF ELECTRICAL SHOCK

1 DO NOT TRY TO PULL OR GRAB THE INDIVIDUAL

2 IF POSSIBLE, TURN OFF THE ELECTRICAL POWER

3 IF YOU CANNOT TURN OFF THE ELECTRICAL POWER, PULL, PUSH OR LIFT THE PERSON TO SAFETY USING A DRY WOODEN POLE OR A DRY ROPE OR SOME OTHER INSULATING MATERIAL

4 SEND FOR HELP AS SOON AS POSSIBLE

5 AFTER THE INJURED PERSON IS FREE OF CONTACT WITH THE SOURCE OF ELECTRICAL SHOCK, MOVE THE PERSON A SHORT DISTANCE AWAY AND IMMEDIATELY START ARTIFICIAL RESUSCITATION

TECHNICAL MANUAL
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HEADQUARTERS
DEPARTMENT OF. THE ARMY
WASHINGTON, DC 28April 1981

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT
AND GENERAL SUPPORT MAINTENANCE MANUAL
PHASE JITTER METER
ME490/U
(HEKIMIAN LABORATORIES, MODEL 48)
(NSN 6625-01-005-7226)

REPORTING OF ERRORS

You can improve this manual by recommending improvements using DA Form 2028-2 located in the back of the manual. Simply tear out the self-addressed form, fill it out as shown on the sample, fold it where shown, and drop it in the mail.

If there are no blank DA Forms 2028-2 in the back of your manual, use the standard DA Form 2028 (Recommended Changes to Publications and Blank Forms) and forward to Coirimander, US Army Communications and Electronics Materiel Readiness Command, ATTN: DRSEL-ME-MQ, Fort Monmouth, NJ 07703.

In either case a reply will be forwarded direct to you.

This manual Is an authentication of the manufacturer's commercial literature which through usage. has been found to cover the data required to operate and maintain this equipment. Since the manual was not prepared In accordance with military specifications and AR 310- the format has not bon structured to consider levels of maintenance.

LIST OF TABLES

LIST Of ILLUSTRATIONS

SECTION 0

INSTRUCTIONS

0-1. Scope

This manual describes Phase Jitter Meter, ME-490/U (figure 1-1) and provides operator and maintenance instructions. Throughout this manual, the ME-490/U is referred to as the Model 48 Phase Jitter Meter.

0-2. Indexes of Publications

a. DA Pam 310-4. Refer to the latest issue of DA Pam 310-4 to determine whether there are new editions, changes, or additional publications pertaining to the equipment.

b. DA Pam 310- 7. Refer to DA Pam 310-7 to determine whether there are modification work orders (MWO's) pertaining to the equipment.

0-3. Forms and Records

a. Reports of Maintenance and Unsatisfactory Equipment. Maintenance forms, records, and reports which are to be used by maintenance personnel at all levels of maintenance are listed in and prescribed by TM 38-750.

b. Report of Packaging and Handling Deficiencies. Fill out and forward SF 364 (Report of Discrepancy (ROD)) as prescribed in AR 735-11-2/DLAR4140.55/NAVMATINST 4355.73/AFR 400-54/MCO 4430.3E.

c. Discrepancy in Shipment Report (DISREP) (SF361). Fill out and forward Discrepancy in Shipment Report (DISREP) (SF 361) as prescribed in AR 55-38INAVSUPINST 4610.33B/AFR 75-18/MCO P4610.19C and DLAR 4500.15.

0-4. Report of Equipment Improvement Recommendations (EIR)

EIR's will be prepared using DA Form 2407, Maintenance Request. Instructions for preparing EIR's are provided in TM 38-750, The Army Maintenance Management System. EIR's should be mailed directly to Commander, US Army Communications and Electronics Materiel Readiness Command, ATTN: DRSEL-ME-MQ, Fort Monmouth, NJ 07703. A reply will be furnished directly to you.

0-5. Administrative Storage

Administrative storage of equipment issued to and used by Army activities shall be in accordance with TM 740-90-1.

0-6. Destruction of Army Electronics Materiel

Destruction of Army electronics materiel to prevent enemy use shall be in accordance with TM 750-244-2.

SECTION I

DESCRIPTION AND SPECIFICATIONS

1-1. General Description

a. The Model 48 Phase Jitter Meter is designed to measure the phase modulation or "jitter", short-term amplitude variations and amplitude dropouts resulting from signal transmission through a voice frequency communications channel. High speed data transmission of 1200 bits per second and above are particularly sensitive to these parameters, which rank in importance with signal-to-noise ratio, impulse noise, frequency response, and envelope delay distortion in determining channel error in performance. Phase jitter and amplitude variations may be introduced by the transmission medium and the terminating, multiplex, carrier and radio equipments. The capability of measuring these important performance parameters and isolating those transmission links or equipments which are causing unacceptable performance is an important and necessary function in maintaining a high grade of service.

b. The Model 48 Phase Jitter Meter measures peak-to-peak phase jitters, phase hits, amplitude hits, amplitude dropouts, and coincident amplitude/phase hits introduced on a 990 to 1030 Hz carrier transmitted through the voice frequency channel under test. A CAUTION indicator warns of incorrect input frequency or level. A switchable 4 milli-second delay on the phase and amplitude hits is provided. The magnitude of the peak-to-peak phase jitter is displayed on a meter while the remaining measurements are displayed on individual mechanical totalizers.

c. The unit is completely self-contained and incorporates a transmit test tone oscillator for making loop measurements without additional equipment. End-to-end measurements may be made using a second Model 48 or any good quality audio oscillator as a test tone source. A 60 minute timer allows unattended collection of data over preset intervals. When totalized data is not required, flashing indicator lamps may be used in place of the mechanical totalizers. An external jitter output is provided to allow chart recording or spectrum analysis, and the externa' carrier output may be used to accurately measure frequency offset and provide a synchronizing signal for observing phase jitter on an oscilloscope. The phase hits, amplitude hits, coincident phaselamphl,I E:l hits, and dropout indicator logic signals are made available through external BNC connectors for use in further defining hit and dropout characteristics.

d. The portable Model 48 is self-contained in a hinged cover transit case measuring 8' high, 14' wide, and 9.5' deep. The rack mounted unit measures 5.25" high, 19' wide, and 16" deep.

1-2. Specifications

a. The mechanical and electrical specifications for the Model 48 Phase Jitter Meter are contained in table 1-1.

b. A photograph of the Model 48 is shown in figure 1-1.

Table 1-1. Specifications

INPUT	
Frequency	990-1030Hz
Level	-40 to + 10dBm
Impedance	135Q, 900Q, Bridge (25,000Q)
Line Hold	135Q, 600Q, 900Q, Positions
Line Hold D.C. Resistance	250Q(maximum)
Longitudinal Balance	Greater than 40 dB
60 Hz to 40 kHz	
TRANSMIT OUTPUT	
Frequency	1020 Hz t 2 Hz
Level	-40toOdBm
Impedance	600Q
METER	
P-P Phase Jitter	30 and 300 Full Scale (:t % of reading plug t 0.2°)
Input/Output Level	- 20 to + 2 dBm (± 1.0 dB)

Table 1-1. Specifications(Continued).

PHASE HITS COUNTER	
Threshold Levels (peak)	5 °steps, 50 to 45 ° (+ 1 °)
Hit Resolution	145 ms
Maximum Count Rate	71sec
Hit Delay (IN)	4 ms
AMPLITUDE HITS COUNTER	
Threshold Levels	±1, 2, 3, and 6 dB
Hit Resolution	145 ms
Maximum Count Rate	7/sec
Hit Delay (IN)	4 ms
COINCIDENCE COUNTER	
Min Coincidence Duration	1 ms
Maximum Count Rate	7/aec
DROPOUTS COUNTER	
Threshold Level	-12 dBm
Min Dropout Durati)m	10 ms
Maximum Count Rate	7/sec
EXTERNAL JITTER OUTPUT	
Impedance	22K Q
Level	75 mv/degree (approximate)
EXTERNAL CARRIER OUTPUT	
Impedance	1OK Q
Level	8v P-P
EXTERNAL LOGIC OUTPUTS (ALL)	
Impedance	2.2K Q
Level	No Hit 0 v Hit + 15.5
TIMER	0-60 minutes with HOLD
TEMPERATURE RANGE	
Operating	0° to + 500 C
Storage	- 10 to + 750 C
VOLTAGE	105 to 125 VAC, 47-400 Hz
POWER	20 watts
DIMESIONS	
Portable	8' high 14" wide 9.5' deep (with cover)
Rack Mounted	5.25' high 19" wide 16' deep
WEIGHT	161bs.

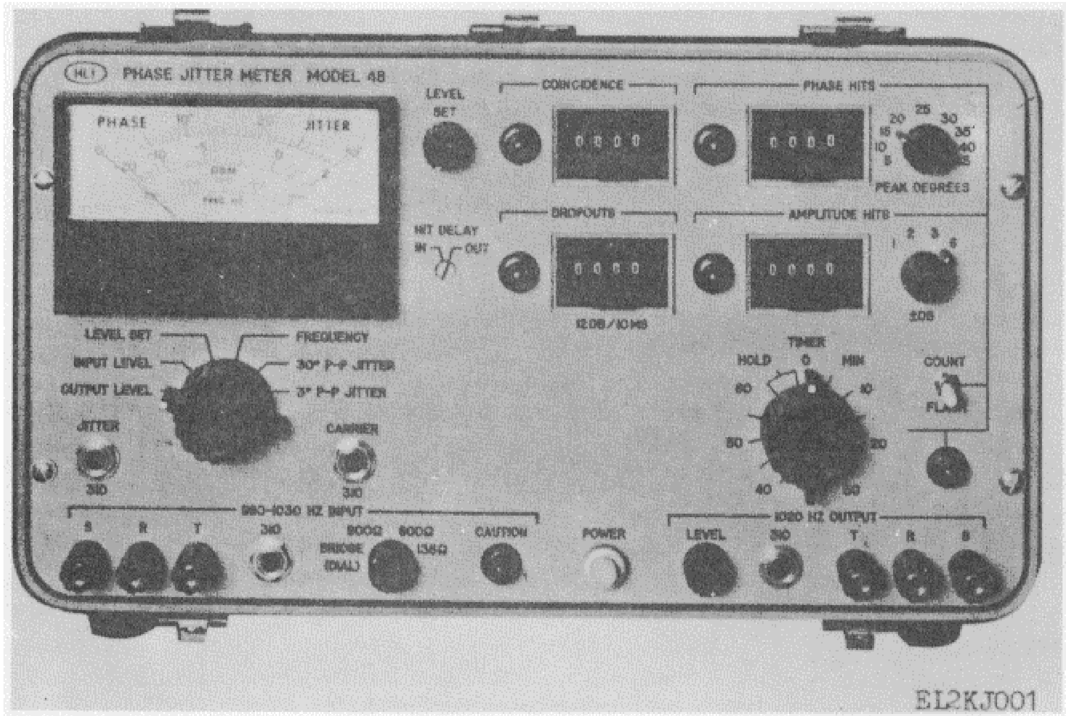

Figure 1-1. The Model 48 Phase Jitter Meter, front panel view.

SECTION II

INSTALLATION

2-1. General

a. The Model 48 Phase Jitter Meter was designed for ease of operation and installation. After the unit has been removed from its shipping container, perform a complete external visual inspection for possible damage.

b. To inspect the interior of the portable unit, open the cover and detach it from the case. Then remove the two screws along the right and left hand edges of the panel and remove the inner assembly from its case. Any damage due to shipping should be immediately reported to the shipping agency.

c. To inspect the interior of the rack mounted unit, remove the seven screws holding the top and bottom covers. Any damage due to shipping should be immediately reported to the shipping agency.

d. All internal adjustments have been set at the factory and no further adjustment is required prior to installation or use of the equipment.

2-2. Portable Unit Installation

a. Primary power is supplied through the line cord packed in the compartmented cover of the transit case. The cover may be opened by pressing the gray tabs of the latches holding the compartment lid. The cord is connected to the AC receptacle located through the access hole on the right hand side of the instrument.

b. Signal input/output lines are connected to the front panel binding posts or Western Electric 310 jacks. Shielded cabling is recommended for all input/output connections.

c. Connection to the JITTER and CARRIER jacks is made using a standard Western Electric 310 tip-ring-sleeve phone plug. The phase hit, amplitude hit, coincident hit, and dropout outputs are available externally on BNC connectors reached from the rear of the unit.

d. For fixed station applications, an optional rack mounting shelf is available. This shelf mounts in a standard 19" relay rack and occupied 121/ inches of vertical rack space. The depth behind the panel is 12" which includes storage provisions for the transit case cover.

2-3. Rack Unit Installation

a. Primary power is supplied through the line cord packed with the instrument. The cord is connected to the AC receptable on the unit’s rear panel.

b. Signal input/output lines may be connected to the front panel binding post/Western Electric 310 jacks or the rear panel mounted barrier strips. Shielded cabling is recommended for all input/output connections. The jitter and carrier signals, together with the phase hits, gain hit, coincident hit, and dropout logic signals, are available at the rear mounted output signal barrier strip.

SECTION III

OPERATION

3-1. General

This section contains a description of the controls and indicators, operating procedures and methods of measurement to be used with the Model 48. Prior to operation, be sure that all connections to the instruments are made in accordance with the instructions of section II, Installation. A photograph of the Model 48 is shown in figure 1-1.

3-2. Controls and Indicators

The controls and indicators used in operating the Mod- el 48 are described in table 3-1. All controls are locat- ed on the front panel. No internal adjustments are re-quired during normal operation. Adjustment procedures for internal controls are contained in Section V, Maintenance and Calibration.

Table 3-1. Controls and Indicators

Designation	Reference	Function
POWER Switch and Indicator Lamp	S101, DS101	Applies AC primary power to the instrument.
INPUTTerminals	J101, 102,103,104	Provides input connections for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
INPUT Switch	S106	Selects input line terminations of 135 ohm, 600 ohm, 900 ohm, or bridging (25,000 ohm) Line hold provided in 135, 600, and 900 ohm positions.
METEER Switch	S102	Selects the input to the front panel meter, measures input/output level peak-to-peak jitter, level set, and frequency.
METER	M101	Displays the parameter selected by the meter switch 8102.
LEVEL SET Control	R120	Sets input signal to an internal reference level of O dBm.
CAUTION Indicator	DS105	Glows when either the input level or frequency is incorrect When active, inhibits all hit counters.
PEAK DEGREES Switch	S103	Selects the threshold degrees (peak) which must be exceeded by the phase jitter to be totalized on the phase hits counter.
PHASE HITS Counter	L102	Totalizes the number of phase hits exceeding the level set on S103.
PHASE HITS Indicator Lamp	DS102	Flashes when a phase hit is detected and S106 is in the FLASH position.
DB AMPLITUDE HITS Switch	S104	Selects the dB threshold which amplitude fluctuations must exceed before being totalized on the amplitude hits counter.
AMPLITUDE HITS Counter	L103	Totalizes the number of amplitude hits exceeding the level set on S104.
AMPLITUDE HITS Indicator Lamp	DS103	Flashes when an amplitude hit is detected and S106 is in the FLASH position.
HIT DELAY Switch	S107	IN position rejects all phase and amplitude hits of less than 4.0 milliseconds duration.
COINCIDENCE Counter	S104	Totalizes the number of coincident phaselamplitude hits which exceed their respective thresholds Will count multiple hits from one source during an extended duration hit from the other source.
COINCIDENCE Indicator Lamp	DS104	Flashes when coincident phase/amplitude hits are detected and S106 is in the FLASH position.
DROPOUTS Counter	L105	Totalizes the number of dropouts which fall below - 12 dBm for longer than 10 milliseconds.
DROPOUTS Indicator Lamp	DS106	Glows during a dropout in both the COUNT and FLASH position of S106.
TIMER	S108	Automatic timer to allow unattended accumulation of data for known time intervals Continuous operation provided in HOLD position.
TTIMER Indicator Light	DS107	Glows when the TIMER is in the ON position.
COUNT/FLASH Switch	S106	Selects the operation of either the counters or indicator lamps.
CARRIER Jack (Portable Unit Only)	J109	Provides the phase locked oscillator signal between tip and ring/sleeve (gnd).
JITTER Jack (Portable Unit Only)	J110	Provides the external phase jitter output between tip and ring/sleeve (gnd).

Table 3-1. Controls and Indicators(Continued)

Designation	Reference	Function
OUTPUT Terminals	J105, 106,107,108	Provides connection to the transmit oscillator, for wire leads, clip leads, banana plugs and Western Electric 310 plugs.
OUTPUT LEVEL CONTROL	R103	Controls the level of the transmit oscillator output.
PHASE HITS (P) Output (Portable Unit Only)	J111	BNC connection for event recording of phase hits.
AMPLITUDE (Portable Unit Only)	J112	BNC connection for event recording of amplitude
COINCIDENCE HITS (C) (Portable Unit Only)	J1 13	BNC connection for event recording of coincidence hits.
DROPOUTS (D) Output (Portable Unit Only)	J114	BNC connection for event recording of the full duration of a drop out
LINE Receptacle	J115	Connects AC line to unit.
INPUT Barrier Strip (Rack Unit Only)	J116	Provides rear panel input signal connections for wire lead s.
OUTPUT Barrier Strip (Rack Unit Only)	J117	Provides rear panel wire connection for output signal, CARRIER and JITI'ER signals and phase, amplitude, coincident and dropout

3-3. Operating Adjustments

This section presents the operational adjustments used with the Model 48. These adjustments are summarized in the OPERATING INSTRUCTIONS on the storage compartment lid located in the cover of the portable case.

a. General.

(1) All adjustments and measurements are made in an idle voice frequency channel using a test signal. The test signal frequency should be between 990 Hz and 1030 Hz which accommodates both the conventional 1000 Hz and 1020 Hz "T" carrier test signals. Measurements are generally made at a test level of -13 dBm. The test set will accept input levels from - 40 to + 10 dBm.

(2) Operating adjustments are made using the actual test signal from the channel. Measurements and adjustments may be made with the test signal from a Model 48 or any good quality audio oscillator. To veri- fy proper instrument operation, the local 1020 Hz out- put signal is looped to the input. Operational checkout procedures are described in paragraph 5-2.

b. Transmit Initial Adjustment.

(1) In accordance with Bell System practice the output level meter always displays the level that would exist if the output were terminated in 600 ohms. To use the Model 48 as a test tone source, first adjust the output LEVEL control for a - 13 dBmO signal using the OUTPUT LEVEL meter switch position. Then connect the OUTPUT terminals to the circuit under test. If this is below -20 dBm, an external level meter may be used in adjusting the LEVEL control, or the following procedure may be used. Loop the output to the terminated input and adjust the output LEVEL control for a level 18 dB higher than required. Adjust the LEVEL SET control for a meter reading of 0 dBm. Now reduce the output LEVEL control until the CAUTION lamp comes on. The output is now set at the required level. As discussed in paragraph 3-4, test signal levels other than -13 dBmO may be used when required.

(2) When using a commercial oscillator be sure both the frequency and level are correct.

c. Receive Initial Adjustment. Connect the channel under test to the 990-1030 HZ INPUT terminals of the Model 48, using either the five-way binding posts or the Western Electric 310 jack. Select the desired terminating impedance and verify the proper input signal level using the INPUT LEVEL meter position, and the proper input signal frequency using the FREQUENCY meter position. Any test signal frequency outside the range of 990 to 1030 Hz will appear as an off-scale or center scale reading with an illuminated CAUTION lamp. Place the meter switch in the LEVEL SET position, and adjust the LEVEL SET control for a 0 dBm reading. This sets the dropout reference level and if the input level drops 12 dB below this fixed level, a dropout will be measured. When the above adjustments have been properly completed, the CAUTION indicator will extinguish. If the CAUTION lamp remains illuminated, verify that the test signal frequency and level are within the operating ranges of the Model 48.

d. Caution Lamp. The CAUTION lamp will illuminate whenever the test signal frequency is outside the 990 to 1030 Hz range or a dropout condition exists. The CAUTION lamp must be extinguished before valid measurements can be made. During a caution period, all hit counters are disabled and no hit data will be accumulated. Following a caution period, internal delay circuitry allows the test set to stabilize before the hit counters are returned to operation. e. Phase Jitter. Following proper adjustment of the LEVEL SET control and the extinguishing of the

CAUTION light , phase jitter measurements may be made. Select the lowest peak-to-peak jitter range which gives a consistent on-scale reading. When short-term fluctuations of the phase jitter are present, the meter reading should be averaged to determine a final measurement figure.

f. Phase/Amplitude Hits. To measure phase and amplitude hits, the desired threshold levels should be selected on the PEAK DEGREES switch and the + DB switch. To totalize measurements on the mechanical counters, place the COUNT/FLASH switch in the COUNT position. If blinking light indications are desired, place this switch in the FLASH position. Before measured data is taken with the counters, reset them to 0 by pressing the manual reset lever located on each counter. To initiate a measurement, turn the TIMER knob to the desired time interval. For intervals of less than 10 minutes the knob must be turned past the 10 minute position and returned to the desired interval. If continuous operation is desired, turn the TIMER knob fully clockwise to the HOLD position. The timer controls the operation of both the counters and the blinking lights.

WARNING

Do not attempt to turn the TIMER knob directly counter clockwise from the OFF position to the HOLD position. This will damage the timer.

g. Coincidence Hits and Dropouts.

(1) The measurement of coincident hits and dropouts are made automatically whenever the timer is on. Operation of the COINCIDENCE HIT counter or blinking light indicator is selected by the COUNT/FLASH switch.

(2) The DROPOUTS indicator light will be illuminated during a dropout condition regardless of the COUNT/FLASH switch position. The DROPOUTS counter will operate only in the COUNT position.

(3) A dropout occurrence will generally produce one phase hit, one amplitude hit, one coincident hit, plus the dropout count. During the dropout period, the CAUTION lamp will illuminate and the hit counters will be disabled. When the dropout is over, internal delay circuitry allows the test set to stabilize before the hit counters are returned to operation and no additional hits are accumulated.

h. Hit Delay. Short duration phase and amplitude hits can be caused by impulse noise. To eliminate the measurement of phase and amplitude hits due to impulse noise, a 4.0 millisecond hit delay is provided which requires a hit to be present for at least 4 milliseconds before it is measured. The hit delay may be disabled by turning the screw driver adjusted HIT DELAY switch on the front panel to the OUT position.

i. Frequency Offset Measurement.

(1) Frequency offset measurements may be made with an electronic frequency counter connected to the tip (signal) and the ring/sleeve (gnd) connections of the CARRIER jack. This output is the phase locked signal which is locked in frequency and phase to the input signal. The phase locked loop effectively provides a narrow band filter of approximately 20 Hz around the test signal resulting in an almost noise free CARRIER output. Extremely accurate and stable measurements may be made even in a noisy channel, normally not suitable for direct frequency offset measurements with an electronic frequency counter.

(2) The CARRIER output may also be used to synchronize an oscilloscope used to observe the channel test signal.

j. External Jitter Output. The demodulated jitter signal is also available on the tip (signal) and ring/sleeve (gnd) of the JITTER jack. This signal may be used for spectrum analysis of the jitter modulation and to determine individual jitter frequencies and their magnitude, and it may also be directly recorded on a high speed strip chart recorder.

k. External Counter Outputs. The dc logic voltages used to drive the counters and/or blinking lights are brought out to individual BNC connectors located on the rear of the unit. A maximum counting rate of 7 pps assures reliable operation of the electro mechanical counters and is compatible with existing Bell System standards. These outputs may be used to make chart recordings of hit and dropout occurrences which then provide a permanent record and detailed picture of circuit performance.

3-4. Measurement Methods

This section presents a general discussion of phase jitter, and the various ways in which the Model 48 may be used to measure this important parameter.

a. General.

(1) Phase modulation or "phase jitter" introduced by voice frequency transmission facilities has an insignificant effect on voice intelligibility, but can introduce errors in data transmission. Just as signal amplitude is affected by channel induced amplitude noise, i.e., thermal, crosstalk, etc., the phase of the signal is affected by channel induced phase jitter. Phase jitter generally occurs during a frequency translation process where power supply hum and power line and ringing frequency ground currents phase modulate the translation oscillators. The resultant jitter has a nominal background level which is displayed on the meter, as well as occasional abrupt changes or hits that are detected by the phase hits counter.

(2) Apparent phase jitter effects may also be generated by other channel parameters, principally additive wideband noise, spurious signals (crosstalk, etc.) and amplitude impulse noise. These parameters are independently specified and measured in evaluating

channel performance, and their effect on the phase jitter measurement has been minimized in the design of the Model 48. Wideband noise, however, may still be a source of error in the phase jitter measurement, and this will result in readings higher than the actual jitter level. Figure 3-1 shows the error which will result as a function of test signal-to-noise level ratios for true phase jitter levels of 11.50 and 10. The test signal-to-noise ratio may be improved by increasing the test tone level up to the point of channel nonlinearity; however, this is generally not recommended.

(3) Degradation in "T" carrier channels is the result of quantizing noise effects rather than the direct phase or frequency modulation of the voice frequency signal. Valid phase jitter measurements may be made over tandem circuits utilizing T carrier, however, they are not necessarily indicative of the "T" carrier channel quality.

(4) Amplitude hits are short term changes in transmission loss which result from a number of causes including automatic level equalization, microwave combiner switching, etc. Amplitude hits are distinct from amplitude impulse noise; however for very high values of impulse noise, test signal level changes may result which appear to be transmission loss varia- tions. The sensitivity of hit measurements to impulse noise is minimized by the hit delay circuitry incorpo-rated in the Model 48.

(5) The coincidence hits measure the number of coincident phase and amplitude hits. This is valuable in determining the source of circuit hits. Certain circuit disturbances will generate both simultaneous phase and amplitude hits, while others will generate only one type.

(6) Dropouts are measured in accordance with Bell Specifications, and are defined as a 12 dB decrease in level for 10 milliseconds or longer. Continuous monitoring and detection of this parameter is virtually the only means of detecting its presence.

b. End-to-end Measurements.

(1) End-to-end measurements are made as shown in figure 3-2. The 1020 Hz test signal may be obtained

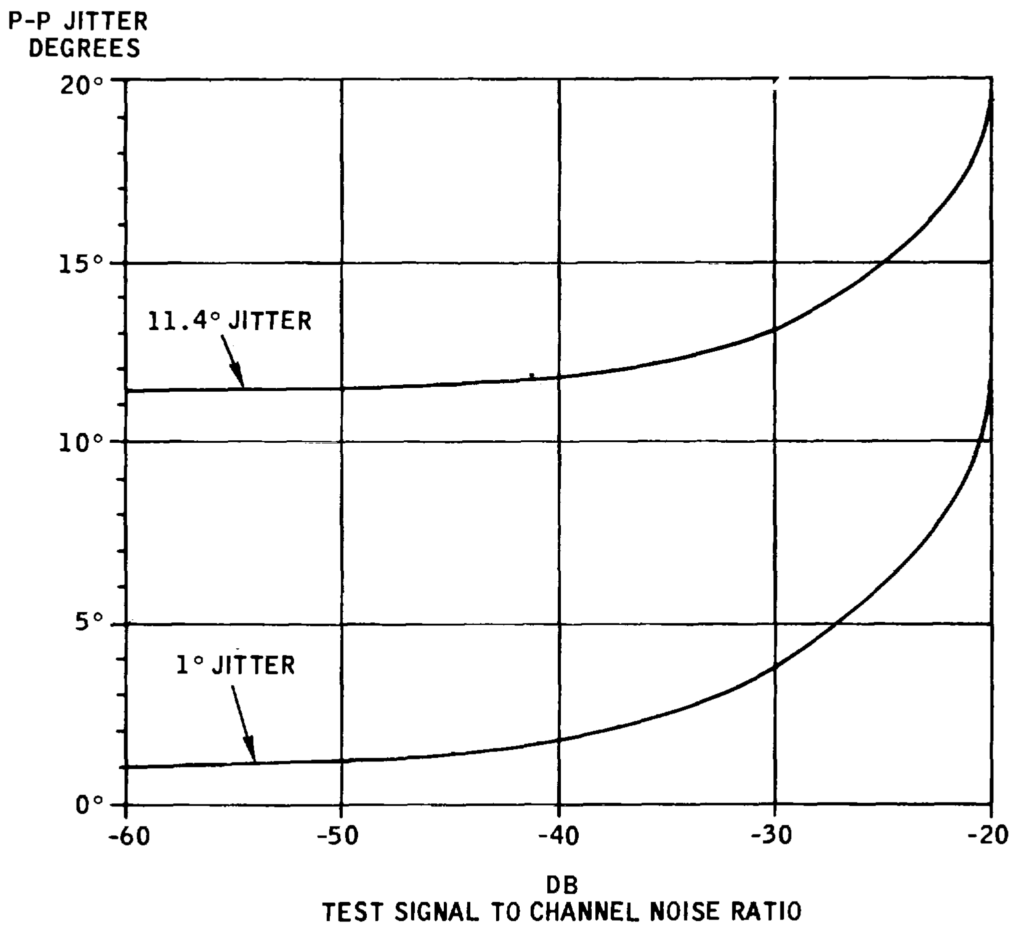

Figure 3-1. Error in P-Pjitter readings resulting from voice frequency channel noise.

from the OUTPUT of the Model 48 or a commercial oscillator. Either balanced or unbalanced circuits may be connected to the input/output of the instrument. The transmission test level is typically - 13 dBmO. The instrument is adjusted, and measurements are made in accordance with the operating adjustments of paragraph 3-3.

(2) To locate sources of excessive phase jitter on a long distance point to point circuit, test signal transmissions from various voice frequency drop points may be used to isolate the segment of the circuit causing excessive jitter. The same techniques may also be used in isolating local sources of jitter, by transmitting test signals from various test points within a facility or equipment.

c. Loop Measurements.

(1) When a far end test signal is not available or it is inconvenient to make end-to-end tests, loop measurements may be performed as shown in figure 3-3. At the distant end, the receive and transmit levels must be matched; i.e. if the specified transmit and receive levels are not equal, it is essential that an amplifier or attenuator network be used to match them. This must be done to preserve the signal-to-noise ratio of the test signal and to eliminate overloading of the transmission facility.

(2) Loop measurements are not as desirable as end-to-end measurements. In general, one cannot assume that the total phase jitter measured on a looped basis is equally divided between the transmit and receive circuits. In some cases, the phase jitter in each direction may tend to cancel, and unlike channel noise, will result in a lower overall loop measurement than the sum of individual end-to-end measurements.

d. Direct High Frequency Carrier Measurement. For direct carrier measurements between 1.0 and 10.0 MHz, a carrier pilot option is offered for the Model 48 which allows direct measurement of any two carrier pilot frequencies. Such measurements are desirable when performing maintenance on various multiplex and carrier equipments and this capability extends the usefulness of the instrument. Typical measurement frequencies are 3.100 MHz and 3.396 MHz. With this option, an additional input selector switch and W.E. 75 ohm coax connector are provided on the front panel, and the carrier pilot level is directly displayed on the INPUT LEVEL position of the meter. The unit maintains its full voice frequency capability.

e. High Frequency Carrier Measurement.

(1) The Phase Jitter Meter may be used with additional equipment to measure phase jitter on carriers in a group or super group baseband. To measure high frequency carriers, it is necessary to use a frequency translation device to hetrodyne the desired carrier to 990 to 1030 Hz. This is done using a tunable selective voltmeter having a translated voice frequency output.

(2) A typical equipment connection is shown in figure 3-4. The selective voltmeter is tuned to the desired carrier, oscillator, or pilot tone frequency, and the translated output is connected to the INPUT of the Model 48. The bandwidth of the translation device should be greater than 800 Hz but not more than 4 kHz.

(3) When looking for low levels (less than 30) of phase jitter using this technique, the signal-to-noise ratio at the output of the selective voltmeter must be taken into account in determining the true value of phase jitter (see figure 3-1). It is also possible that the translation device itself may introduce jitter in the translated signal; this may be verified by measuring a carrier source having known jitter.

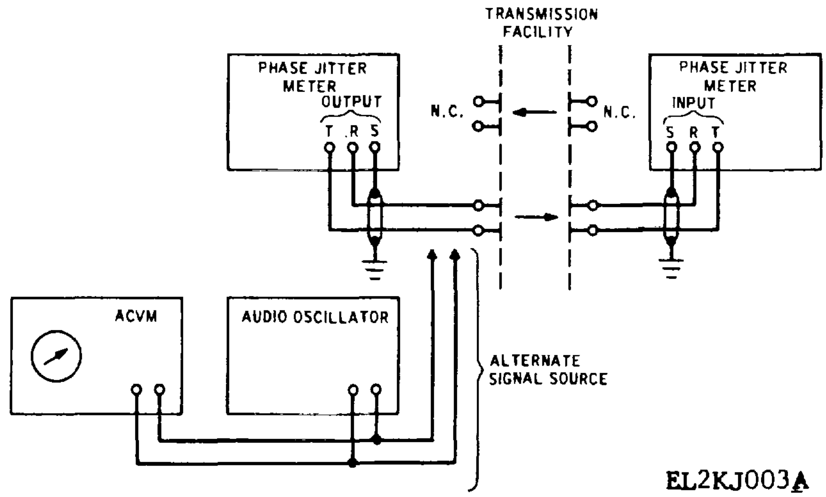

Figure 3-2. End-to-end measurement.

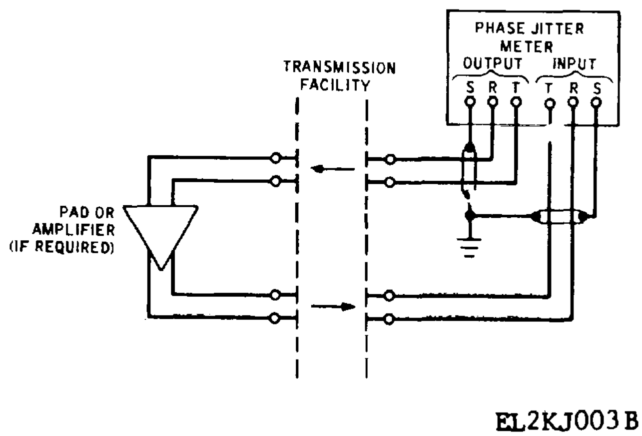

Figure 3-3. Loop measurement.

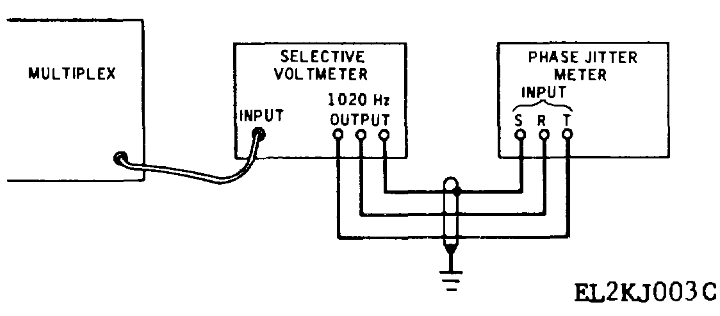

Figure 3-4. High frequency carrier measurement.

SECTION IV

THEORY OF OPERATION

4-1. General

This section provides a general theory of operation followed by detailed circuit operation on a functional block basis. The Model 48 is entirely solid state and makes extensive use of integrated circuit differential operational amplifiers and conventional discrete com- ponents. Two types of differential operational ampli- fiers are used in the unit. Where wide bandwidth and fast rise times are required, the externally compen- sated Type MC1437 is used, and where a 10 kHz band- width is adequate, the internally compensated Type MC1458 is used. Discussions of operational amplifier configurations and operation are available in a number of current reference texts. Conventional transistors are used in the remainder of the circuitry. A simplified block diagram of the Model 48 is shown in figure 4-1.

a. Input. The balanced or unbalanced input signal is terminated by the input switch in 135 ohm, 600 ohm, 900 ohm, or bridging impedances. Line holding is provided in the 135, 600 and 900 ohm positions by a holding coil. Dual isolating capacitors precede the input transformer, and reject the D.C. voltages which appear at the input. The transformer is connected to a 5 pole low pass filter which attenuates spurious signals and noise above 2.0 kHz. This filter is followed by a level set amplifier whose gain is manually set to provide a 0 dBm reference level for the dropout measurement.

b. Phase Jitter Measurement.

(1) The filtered 0 dBm input signal from the level set amplifier is routed to the signal limiter which provides a square wave replica of the input signal zero crossings, and becomes one input to the digital phase detector. This detector compares the input signal with the long time constant phase locked reference oscillator and generated DC pulses whose width are proportional to the phase difference. These pulses are then changed to a DC voltage proportional to that phase difference by the 300 Hz low pass filter. This filter's out- put is used to control the phase locked reference oscillator, and supplies the phase jitter signal to the phase hits detector and peak-to-peak jitter detector. The phase hits detector is followed by a 4.0 millisecond hit delay circuit which is designed to reduce measurement sensitivity to impulse noise by requiring that a phase hit be present for a minimum of 4 milliseconds before its occurrence is passed on to the phase and coincident hit drivers.

(2) The signal limiter also supplies an input to the out of lock detector, which is combined with the output of the dropout detector to generate the CAUTION light indication. The caution detector output is used to inhibit all of the hit counters/lights during a caution condition and ensures that no invalid data is accumulated.

c. Amplitude/Dropout Measurement.

(1) The filtered 0 dBm input signal from the level set amplifier is also applied to the amplitude detector, which consists of a full wave rectifier feeding a 300 Hz low pass filter identical to that following the digital phase detector. The filter's DC output, which is proportional to the input level, is applied to the amplitude hit reference amplifier and the plus and minus amplitude hit detectors. These circuits detect amplitude variations exceeding the preset threshold values, and the plus and minus hit outputs are combined prior to the 4.0 millisecond hit delay circuitry. The hit delay out- put provides a signal to the amplitude hits driver and to one input of the coincidence detector which detects simultaneous phase and amplitude hits and furnishes the input to the coincident hits driver.

(2) The filtered DC amplitude output signal is also used to detect dropouts. When the dropout detector measures more than a 12 dB decrease in the input signal level for a period exceeding 10 milliseconds, a dropout condition is generated. The dropout signal is used as an input to the caution detector and to the dropout driver and indicator.

4-2. Detailed Circuit Operation

a. Line Input. The input signal is connected using a five-way binding post or a Western Electric type 310 jack. Both balanced and unbalanced signals may be accommodated. The input is terminated by the INPUT switch S105, and DC holding coil L101 is connected across the input in the 135, 600 and 900 OHM termination positions. In the BRIDGING position (approximately 25K input impedance), the holding coil is removed to allow dial-through operation. The signal is then applied to the two d.c. isolating capacitors C201 and C202 which also reject 60 cycle pick-up on the line. The filter's output is connected to the input transformer T201 which performs the balanced to unbalanced transformation. The transformer secondary feeds a low pass filter IC201B, IC202B, which pro-

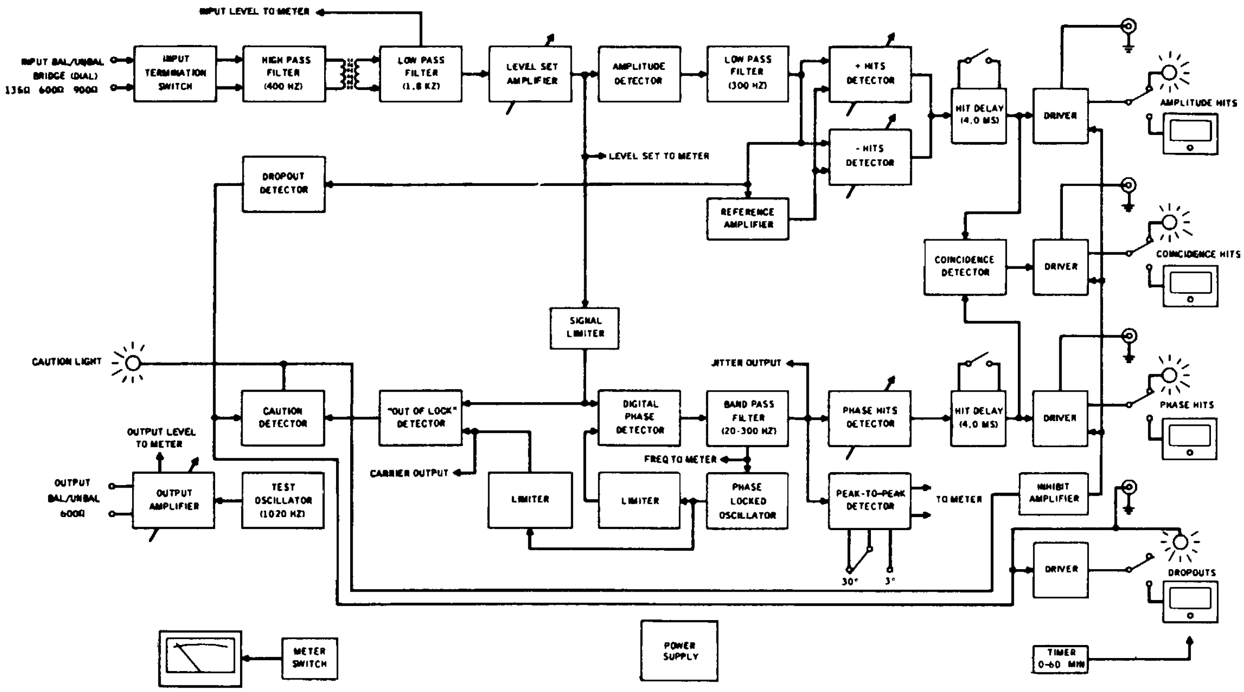

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Figure 4-1. Model 48 block diagram.

vides a 5-pole Butterworth response using active filter techniques, eliminating the requirement for conventional inductors. Input voltage transient protection is supplied by diodes D201, 202. The output of IC202B provides the filtered input signal utilized by the input level set amplifier IC202A. The gain of the level set amplifier is controlled by the front panel LEVEL SET ;ontrol R120 and may be varied from - 10 dB to + 40 dB to provide a 0 dBm level at its output pin G. Maximum gain is limited by R212, and C210 provides DC stabilization of the amplifier.

b. Signal Limiter. The input signal limiter IC301B is a differential operational amplifier used as an open loop gain zero crossing detector with DC stabilization provided by R303, 306, C339. Amplifier phase compensation is provided by C301, 303. This amplifier provides a square wave replica of the input signal zero crossings.

c. Digital Phase Detector. The output from IC301B and the phase locked reference oscillator output from IC302A are connected to the two inputs of the digital phase detector. Transistors Q301, 302, and their associated components form an "exclusive or" gate which provides a bipolar output pulse whose width is proportional to the phase difference (zero crossings times) of the two inputs. The back-to-back zener diodes D306, 307 provide a constant amplitude to the circuitry that follows.

d. 300 HZ Low Pass Filter. The carrier frequency present at the output of the digital phase detector is removed, and the upper limit of the phase jitter spectrum determined by the low pass filter consisting of IC303A, B, and their related components. This filter provides a 5-pole 300 Hz Butterworth response using active filter design techniques. To achieve the desired bandwidth accuracy, 1% resistors and 5% capacitors are used in this filter. The output of the first active filter section IC303B pin 7 furnishes the signal to the FREQUENCY position of the panel meter through R327, 338 and the bias offset network R328, 329. The phase locked loop control voltage is obtained from the output of the full 5-pole filter at IC303A.

e. Phase Locked Referenced Oscillator. The output of the low pass filter is a DC voltage proportional to the instantaneous phase difference between the input and reference oscillator signals. This voltage is further filtered by the network R346, 347, and C319. This network provides an over-damped phase locked loop response characteristic and its output controls a conductance modulator consisting of Q310, 311, 312, and D308, 309. This circuit effectively varies the reactance across the "bridge tee" oscillator feed back circuit, and determines the output frequency and phase of the oscillator. The oscillator frequency is adjusted by trimmer R358. Its output is connected to the reference limiter IC302A which provides a square wave replica of the phase locked oscillator signal to the digital phase detector.

f. 20 HZ High Pass Filter. The output of the 300 Hz low pass filter is high pass filtered by IC304B, which is a 2-pole 20 Hz active filter, using C314, 315, R335, 337, 393, 394, and 395. This filter also provides isolation and signal amplification for the circuits that follow it. The jitter output to the JITTER jack Jl10 is supplied through R336.

g. Peak-to-Peak Detector. The high pass amplifier feeds the high linearity peak-to-peak detector consisting of amplifier IC304A, the positive peak detector Q307, and the negative peak detector Q308. The gain of the detector is controlled by the meter switch providing near unity amplifier gain in the 300 position, and 10 times that gain in the 30 position. R341 provides the calibration of the 300 range and R342 ad- justs the calibration of the 3° range. The positive peak is stored on capacitor C318, and the negative peak on capacitor C317. Their outputs are applied to the meter through multiplier resistor R345. This detector is cali- brated in terms of peak-to-peak value of a sine wave and responds to approximately the 98% level of white noise.

h. Phase Hits Detector.

(1) The phase hits detector consists of the full wave rectifier IC305A, B, and a variable threshold detector IC306A.

(2) The jitter signal is applied to the full wave rectifier IC305. This circuit provides a highly stable precision full wave rectifier, independent of diode offset characteristics. Its output represents the peak value of the phase jitter, as opposed to the peak-to-peak reading which is displayed on the meter. The output is connected to a threshold detector IC306A which compares this peak signal to the threshold level set by the PEAK DEGREES switch S103. The output of the threshold detector remains at a negative value until the peak phase jitter signal exceeds the threshold level. When this occurs, the output abruptly changes to a positive voltage until the input signal again falls below the threshold, returning the output to the negative level.

i. Four Millisecond Hit Delay. The output of the phase hits threshold detector is connected to a 4 millisecond hit delay circuit consisting of Q309, IC306B. When a phase hit occurs, Q309 is turned off, allowing C337 to charge towards the supply voltage. The time constant is selected so the capacitor voltage crosses the trigger amplifier threshold in 4 milliseconds, resulting in a change of state of the trigger amplifier output. This change is used to drive the phase hits counter driver circuitry and coincidence detector. If the phase hit is terminated prior to the 4 millisecond interval, C337 is immediately clamped to ground by Q309, thus terminating its charging cycle. Phase hits of less than 4 milliseconds duration will not generate an output, thus providing the desired immunity to impulse noise. The hit delay is present when the delay capacitor C337 is grounded at terminal V.

j. Phase Hits Driver. The phase hits, amplitude hits, coincidence hits and dropout counters, with their respective indicator lamps, use identical counter driver circuitry. A single explanation is given for the phase amplitude hits driver and this may be used with appropriate substitution of component designations for the other driver circuits.

k. Out of Lock Detector.

(1) The out of lock detector is used to detect an "out of range" lock ot lack of phase lock in the reference oscillator. This is then combined with the dropout detector to illuminate the CAUTION lamp if either the phase lock or input level are incorrect.

(2) The out of lock detector uses a digital phase detector Q303, 304, similar to that of the jitter phase detector. It is driven by the input signal limiter IC301B and the out of lock limiter IC302B, which utilizes a 900 phase shifted input signal obtained through the network R359, C308. This results in a maximum positive voltage output from the digital phase detector that corresponds to the center scale meter reading in the FREQUENCY meter position. As the input frequency is varied in either direction, the voltage becomes less positive, and the out of lock threshold detector IC301A is set to provide a change of output when the acceptable phase lock range has been exceeded. When phase lock has not been obtained, the output voltage has an average value of 0 volts which generates an out of lock indication from the threshold detector. The output of the digital phase detector is summed through R310, 319, with the threshold set voltage from R320. Hysteresis is provided in the threshold detector by R321, 322. When an out of lock condition exists, a positive voltage appears at the output of IC301A.

l. Amplitude Detector. The amplitude detector consists of a full wave rectifier IC201A, 203A, similar in operation to the full wave rectifier of the phase hits detector IC305. This full wave rectifier uses diodes in the feed back network to provide a half wave rectified replica of the input signal at the junction of R216, D204. This signal is then summed by a ratio of 2 to 1 with the original signal through R217, 213, to provide the full wave waveform at the output of IC203A.

m. 300 HZ Low Pass Filter. The full wave detector is followed by a 5-pole active 300 Hz low pass filter consisting of IC203B, 204B. The filter configuration is similar to the 300 Hz low pass filter of paragraph 4-2d. Different circuit values are utilized to provide an overall filter gain of 6 dB.

n. Reference Amplifier and Hits Detector.

(1) The output of the low pass filter is connected to the reference amplifier and hit detectors. Dual threshold detectors are set to change state whenever an increase or decrease in signal level occurs which exceeds the setting of the + DB front panel switch S104. The outputs of these detectors are then combined to drive the amplitude hit delay circuitry.

(2) The short term average of the filtered signal output is obtained by the time constant circuit R230, C223, and is applied to the input of the reference amplifier IC204A, and amplified by a factor of 2. The gain is controlled by the resistor divider network consisting of R113 through 119, and the amplitude hits + DB switch S104 selects the voltages on this divider chain corresponding to + 1, 2, 3, or 6 dB levels, which become the reference inputs to the amplitude hit threshold detectors.

(3) The threshold detectors IC205A and B compare the output of the 300 Hz filter, which contains the short term amplitude variations of the input signal, with the divided average values from the ± DB switch. A small hysteresis is provided by the feedback resistors R233 through 236, and compensation is provided by capacitors C216, 217, 219, 220. When an amplitude hit occurs which exceeds the threshold setting, the output of the appropriate threshold detector will change from a positive to a negative voltage, and this is applied to the 4 millisecond hit delay circuit through diodes D205, 206. The operation of the hit delay circuit consisting of Q230 and IC206B is identical to that described in paragraph 4-2i. The output of the hit delay circuit is connected to the amplitude hits driver Q201 through 206.

o. Amplitude Hits Driver.

(1) The amplitude hits driver is identical to the phase coincidence and dropout drivers and the following explanation may be used for these circuits. The driver operates either the counter or the indicating lamp as controlled by the COUNT/FLASH switch S106.

(2) The input signal is differentiated by the input capacitor C230A and the positive going edge is removed by D216A. The negative going pulse is applied through R276A to the multivibrator consisting of Q204, 205. The multivibrator provides approximately a 70 millisecond "on" pulse followed by a 70 millisecond "off" pulse which is required for the mechanical counter operation. This results in a maximum count rate of 7 counts per second. The multivibrator output is amplified by Q202 which feeds the driver transistor Q201. Transient protection for the driver is provided by R285A and D217A. Inhibiting transistor Q206 is included in all except the dropout detector driver, and inhibits the multivibrator operation when a positive signal is obtained from the caution detector. This

eliminates the accumulation of invalid data during periods when a caution condition is present.

p. Coincidence Detector Circuitry. Coincidence between the phase and amplitude hits is detected by diodes D209, 210. These diodes will have a negative output only when both of the inputs have dropped to a minus voltage. When this occurs, a negative impulse is fed to the coincidence hits driver consisting of Q207 through 212. See paragraph 4-20 for a description of the driver operation.

q. Dropout Detector.

(1) The dropout detector monitors the input signal level from the 300 Hz low pass filter and is activated when the input signal drops 12 dB below the reference level for a period exceeding 10 milliseconds. The reference level is set when the LEVEL SET control is adjusted for a 0 dBm meter reading in the LEVEL SET meter position.

(2) The dropout detector consists of the threshold detector IC207A, 207B and the timing circuit Q229, and IC206A. The low pass filter output is connected to one input of the signal threshold detector IC206A where it is compared against the threshold voltage set by R246. This may be adjusted over a range of - 5 to - 30 dB; it is factor set at - 12 dB. The timing circuit Q229 and IC206A is identical to the hit delay circuit of paragraph 4-2i. Capacitor C224 determines the dropout detector time constant and rejects dropouts having durations of less than 10 milliseconds.

(3) The positive output of IC206B during a dropout condition, drives the dropout driver circuitry through Q224. The dropout lamp is driven continuous- ly through the darlington pair driver Q225, 226, so that it will remain lit during the entire dropout interval. The dropout signal is also used as one input to the caution indicator.

r. Caution Detector.

(1) The caution detector combines the dropout and out of lock detector outputs so that the caution lamp is illuminated whenever either is unacceptable.

(2) Diodes D213, 214 combine the positive outputs from the out of lock and dropout detectors to generate a caution condition. This positive voltage also inhibits the amplitude hits, phase hits and coincidence hits multivibrators through Q206, 212, and 218 respectively. In addition, this voltage drives the darling- ton pair Q227, 228 which controls the CAUTION lamp. Capacitor C227 provides a delay in removing the caution voltage from the multivibrator inhibit circuitry to allow the phase locked oscillator and amplitude hits circuitry to stabilize before data is again accepted by the counters.

s. Timer. The mechanical timer S108 controls the DC voltages to the counters and their associated indicator lamps. When the timer is ON, the timer ON-OFF lamp DS107 is illuminated.

t. Meter Circuit. INPUT/OUTPUT levels, P-P PHASE JITTER, LEVEL SET, and FREQUENCY are monitored using the front panel mounted 50 microampere meter. The meter input is selected by the meter switch S102. For level monitoring, a bridge rectifier consisting of D314, 315, and R390, 391, 392 with DC isolating capacitor C338, is used to rectify the audio voltages.

u. Transmit Oscillator. The transmit oscillator IC308 is a low distortion design using a gyrator in place of an inductor. Its output is connected to the output LEVEL control R103 which feeds the output amplifier IC309A. It is a transformer coupled to the OUT-PUT terminals and provides a low distortion, 1020 Hz, -40 to 0 dBm, 600 ohm test tone source for use in back-to-back and loop testing.

v. Power Supply.

(1) A dual tracking + 15 and -15 volt DC power supply is utilized in this instrument. It provides .01% line and .05% load regulation, and has a temperature coefficient of .020 per degree C. Noise and ripple on the power supply output are 4.0 millivolt rms maxi- mum. Current capacity is 200 milliamperes for each supply voltage. The unregulated 28 volt DC power sup- ply for the counter and indicator lamps is also provided by the power supply board.

(2) The power supply is controlled by the front panel on-off push switch S101. A 1/2 amp slow-blow fuse F101 is provided for protection of the line circuitry.

(3) The power supply receives the low voltage ac from transformer T101. This transformer has a dual primary and is suitable for 1151230 volt ac operation (optional). A center tapped secondary feeds the full wave rectifiers and filter capacitors for the dual 15 volt supply. The zener reference voltage from D405 is amplified by transistors Q405, 408, which regulate the series pass transistor Q401. Current limiting is pro-vided by Q404 and is set for 200 milliamps. Output voltage is controlled by R416. Additional filtering is provided by C407 and reverse voltage protection is provided by diode D403.

(4) A similar arrangement is used in the + 15 volt regulated supply. This regulator obtains its reference voltage from the -15 volt supply to provide tracking outputs.

(5) The second winding of the power transformer provides the low voltage ac input to the unregulated, unfiltered 28 volt supply. The transformer output is rectified by D402 and transient suppression is provided by C403. No additional filtering is required.

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SECTION V

MAINTENANCE AND CALIBRATION

5-1. Maintenance Philosophy

Maintenance procedures for the Model 48 are divided into preventive and corrective classifications. Preventive maintenance consists of the routine performance checks which may be made using the front panel controls of the instrument. Corrective maintenance covers the symptom analysis, trouble shooting, repair and recalibration of the instrument.

5-2. Preventive Maintenance

a. General.

(1) The preventive maintenance procedures described in the following sections are used by the operator and maintenance personnel to verify proper instrument operation using the front panel controls. If proper operation is not achieved, see paragraph 5-3 for corrective maintenance procedures.

(2) Periodic cleaning, lubrication or inspection of the Model 48 is not required.

(3) All of the following checks are made using the 1020 HZ OUTPUT signal as an input. Connections between the OUTPUT and INPUT terminals may be made using clip leads or an appropriate test cord. The LEVEL SET control is adjusted in accordance with paragraph 3-3 for all of the following checks.

b. Input/Output Level Check.

(1) Place the meter switch in the OUTPUT LEVEL position and verify that the output level may be adjusted over a - 20 to 0 dBm range. Set the OUTPUT LEVEL control at 0 dBm, and then monitor the input level. The reading should agree within + 0.5 dB of the output level reading.

(2) Absolute calibration of the internal level meter may be checked by comparison with an external standard meter connected in parallel across the INPUT terminals.

c. Jitter Measurement Check. Verify that both the 30 and 300 P-P JITTER positions of the meter switch indicate less than 0.150 and 1.50 residual readings respectively. Chance the INPUT switch between the BRIDGE and 900 ohm positions repeatedly on both ranges and verify that an upscale reading occurs during the switch transitions.

d. Phase Hit, Amplitude Hit, Coincidence Hit, and Dropout Check.

(1) Place the TIMER in the HOLD position, the phase hits PEAK DEGREES switch in the 150 position and the amplitude hits + DB switch in the + 6 position.

(2) Remove the input signal (both leads must be removed simultaneously) and verify that a single phase hit, amplitude hit, and coincidence hit occur. A dropout indication should occur 1/,0 second after removal of the input signal. When the input signal is reapplied, verify that no additional hit counts are tota- lized.

e. Caution Indicator Check. When the input signal is removed, verify that the CAUTION lamp lights either before or simultaneously with the DROPOUT indicator. When the input signal is reapplied, the CAUTION lamp will remain lit for a fraction of a second after the DROPOUT indicator has extinguished.

5-3. Corrective Maintenance

a. Troubleshooting.

(1) This section covers symptom analysis, circuit level troubleshooting and calibration procedures for the Model 48.

(2) No specialized mechanical assembly or disassembly procedures are required. Accepted practices should be followed when repair is undertaken on main frame components or the printed circuit boards. Recommended troubleshooting techniques are based on signal tracing methods where a known input signal is used and the level and waveforms are verified as the signal progresses through the circuitry. Typical test equipment required to perform the troubleshooting procedures are listed in table 5-1.

Table 5-1. Maintenance Test Equipment

Description	Typical model number
Audio oscillator	HP 204C
Calibration test jig	See paragraph 5-3d(5)
AC voltmeter	HP 400 EL
Oscilloscope, single channel, 1 MHz frequency response	Tektronix 323
Multitester	Simpson 260

b. Symptom Analysis. The preventive maintenance checks of paragraph 5-2 are used to isolate the area in which malfunction occurs. Table 5-2 summarizes possible fault locations for each of the preventive maintenance tests.

Table 5-2. Symptom Analysis

Preventive maintenance test	Probable trouble locations
1 No response from any test	a AC power cord
	b Fuse
	c Internal A.C wiring or power switch S101
	d Power supply
2 Input/Output level check	a IC308 IC309A
	b Meter switch S102, meter level rectifiers D314, 315
	c MeterM101
3 Jitter measurement check	
Unable to LEVEL SET	a IC201B, 202
	b LEVEL SET control R120
	c T201
No P-P JIT'TER reading	a IC308 frequency incorrect
	b IC301B, IC302B, Q301, 302, IC303, Q310, 311,312
	c IC304, Q307, 308
	d Meter switchS102
4 Hit check	
4.1 Phase hits check	a IC305, 306, Q309, 213 thru 218
	b 28 VDC supply, T101
	c Counter L102, COUNTIFLASH switch S 106
	d PEAK DEGREES switch S103
4.2 Amplitude hits check	a IC201A, 203, 204,205, 206B, Q230, Q201 thru 206
	b Counter L103, COUNT/FLASH switch S106
	c + DB switch S104
4.3 Coincidence hits check	a Q207 thru 212, D209, 210
	b CounterL104
	c COUNTIFLASH switch S106
4.4 Dropout check	
No counter operation	a IC206A, 207, Q219 thru 224
No light operation	b Q225,226
5 Caution indicator check	a Q227, 228, D213, 214
	b IC301A, 302B, Q303, 304
6 Power supply ± 15 VDC	a TransformerTl01
	b Q401,402
	c Q403 thru Q408

c. Circuit Level, Troubleshooting. The following sections describe the general procedures to be used in locating malfunctions. Where appropriate, performance standards, voltage levels, or waveform descriptions are provided to assist in the troubleshooting procedures. When a circuit has the proper input signal but the correct output cannot be measured, the components associated with that circuit should be checked and replaced if defective. Before detailed troubleshooting is undertaken, the + 15 volt power supply voltages should be checked. Low supply voltages may result from a malfunctioning power supply or excessive current being drawn by a defective circuit. A defective integrated circuit may often be located by feeling the case temperature. Normally, the integrated circuits are moderately warm to the touch. However, when defective, they can become extremely warm, causing a painful sensation when touched.

(1) 1020 HZ Output Circuitry. The output oscillator is checked using an oscilloscope. Under normal operations, a 12 volt peak-to-peak sine wave will be seen at terminals 300-2 and 300-Z, when the output LEVEL control R103 is fully clockwise. If no output is seen, check the oscillator circuit of IC308. If the proper signal is present but no 1020 Hz output is seen, check the amplifier IC309A and the transformer T301. The output frequency may be verified using an electronic frequency counter connected directly across the 1020 Hz OUTPUT terminals.

(2) Input Circuitry. The input circuitry is checked using a 0 dBm 1020 Hz input signal. Verify with an oscilloscope that an input signal with a level of approximately 0 dBm is present at the output of the first low pass filter stage IC201B pin 7, and the output of the second low pass filter stage IC202B pin 7. If 0 dBm cannot be obtained, check for input signals on both sides of the input transformer T201. With this input signal, verify that 0 dBm can be obtained at terminal 200-G by adjusting LEVEL SET control R120. With the oscilloscope verify that the output signal or terminal 200-G appears on terminal 300-D. Verify that a + 12 volt or greater square wave at the test fre-

quency is present at the output of the signal limiter IC301B pin 12. This waveform is shown in figure 5-1A. If this waveform is not seen, or if either peak voltage is less than 10 volts, replace IC301. The input level meter may be checked using the same input signal. The input-output level meter positions should read within + 0.5 dB of the standard level as measured by an external reference voltmeter. Calibration instructions are given in paragraph 5-3d(2).

(3) Phase Locked Oscillator. The phase locked oscillator incorporates the phase detector Q301, 302, the low pass filter IC303, a reactance modulator Q310, 311, 312, oscillator IC308, and limiter IC302A. With no input signal, check with an oscilloscope for a 10 volt peak-to-peak or greater sine wave at pin 1 of IC308A. If no signal is seen, check Q310, 311, 312, and their associated components. If this signal is present, verify that a + 12 volt or greater square wave is present at the output of the reference limiter IC302A pin 2. This waveform is shown in figure 5-1A. Connect a 1020 Hz test signal to the input, and adjust the instrument in accordance with paragraph 3-3. Verify that a + 6 volts pulse train is present at the junction of R316, 317, and D306. When the CAUTION light is extinguished, the waveform shown in Figure 5-lB should be seen. Note that this waveform has a frequency of twice the input frequency, i.e. 2080 Hz. Place the instrument in an out of lock condition by changing the input frequency to 1100 Hz (CAUTION light on) and monitor the output waveform of the first phase jitter low pass filter section IC303B pin 7. This waveform is shown in figure 5-1C, and will be a somewhat distorted isosceles wave varying at the difference frequency of the input test signal and the phase locked oscillator frequency. Verify that a similar isosceles waveform is seen at the output of the second low pass filter stage IC303A pin 1.

(4) Peak-To-Peak Detector. The output of the low pass filter is AC coupled to the high pass filter stage IC304B, and then to the peak-to-peak detector IC304A, Q307, Q308. In the out of lock condition, an isosceles waveform similar to figure 5-1C should be seen at the high pass filter output IC304 pin 7. It may have its peak slightly clipped and will have an amplitude of approximately + 12 volts. With the meter switch in the LEVEL or FREQUENCY position, the DC voltage across the peak-to-peak detector capacitor C318 will be + 2 to + 5 volts and - 2 to - 5 volts across C317.

(5) Phase Hits Detector. The phase hits detector takes the output of the high pass filter IC304B and full wave rectifies the signal in IC305. This rectified signal is then fed to a threshold detector IC306A whose threshold is set by the front panel PEAK DEGREES switch. The detector output is connected to the 4 milliseconds hit delay circuit, consisting of Q309, IC306B. In the out of lock condition and with the PEAK DEGREES switch in the 450 position, verify that a full wave rectified isosceles wave is seen at pin 1 of the IC305A. It will have an approximate amplitude of 0 to + 10 volts. The threshold detector IC306A should have a + 12 volt nearly square wave output at pin 2. If this waveform is not seen, carefully check the phase hits switch for dirty or bad contacts, and check IC306. With the HIT DELAY switch in the ON position and using an oscilloscope, observe the waveform in the 4.0 msec hit delay circuitry at the junction of R384, C337, and D313. This waveform is shown in figure 5-1D. When this waveform crosses the -7.5 volt delay threshold level, the output of the hit delay detector IC306B will change from + 12 to -12 volts. Verify with an oscilloscope that this occurs.

(6) Phase Hit Driver. The multivibrator circuit values are arranged to provide an "on" time of approximately 70 milliseconds followed by an "off" time of equal minimum duration. The procedure of paragraph 5-3c(10) used to trouble shoot the multivibrator and counter driver.

(7) Out of Lock Detector. The out of lock detector compares the limited input signal with the limited 900 phase shifted reference oscillator signal from IC302B in the digital phase detector Q303, 304. The phase shifted reference oscillator output from IC302 pin 12 should resemble that shown in figure 5-1A. In the out of lock condition, the voltage at the input of the out of lock detector IC301A pin 5 should be negative. (Use an oscilloscope to observe.) In the locked condition, the voltage should be positive. As this DC voltage goes from + to -, the output of the threshold detector IC301A pin 2 should change from + 12 volts to -12 volts as measured at terminal 300-H.

(8) Amplitude Detector. The amplitude detector consists of a full wave rectifier IC201A, 203A, followed by a 300 Hz low pass filter IC203B, 204B. The input to the full wave rectifier is the same filtered input signal supplied to the phase jitter measurement circuitry. With a 0 dBm meter reading in the LEVEL SET position, a - 2 volt peak-to-peak full wave rectified 1020 Hz sine wave will be seen at the output of IC203A pin 1. If measured with a DC meter, the voltage will be approximately -1 volt. When the input signal is removed, the voltage at pin 1 should be 0 +0.1 vdc. With approximately -1 vdc from the full wave rectifier, the output of the low pass filter IC204B pin 7 will be - 2 vdc. When the input signal is removed, this voltage should drop to 0 + 0.1 vdc.

(9) Amplitude Hits Detector. The amplitude hits detector consists of the reference amplifier IC204A, and the + hit detectors IC205. The -2 vdc output from the 300 Hz low pass filter is supplied to the reference amplifier through the integrating network R230, C223. This amplifier has a gain of 2 which re-

sults in an output voltage at pin 1 (terminal 200-0) of - 4 vdc. If this voltage is not measured, it is likely that the + DB switch or some of its associated resistors are defective. Verify that when the input signal is removed, the output voltage drops to 0 + 0.1 vdc. In the ± 6 dB position of the amplitude hits switch, the voltages at terminals 200-K, -L, will be approximately -4 vdc and -1 vdc respectively. When no level changes are present, the outputs of the hit detectors IC205 pins 12 and 2 will be - 12 vdc. When amplitude hits are generated in accordance with paragraph 5-2, the hit detector outputs will become + 12 vdc during the hit detection. This may be verified with an oscilloscope. Verify that these amplitude hits also appear at the junction of D205, 206. The hit delay circuit Q230, IC206B may be checked in accordance with paragraph 5-3c(5).

(10) Amplitude Hits Driver. The multivibrator provides an "on" time of approximately 70 milli seconds, followed by an "off" time having equal mini-

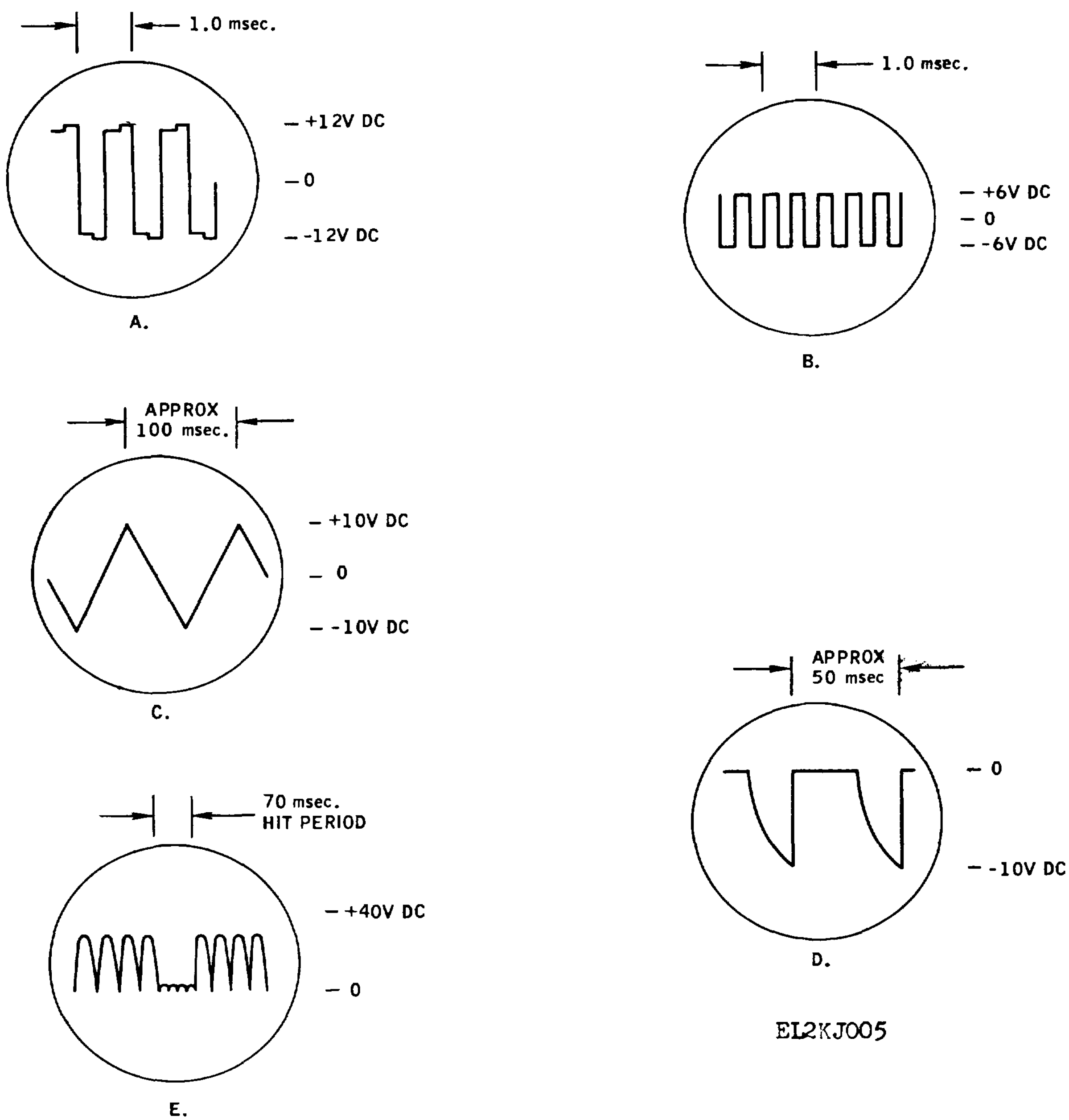


Figure 5-1. Model 48 Waveforms.

mum duration. The following procedure may be used to trouble shoot all of the multivibrator/driver circuits:

(a) The negative going hit signal is differentiated by C230 to provide a 15 volt or greater trigger pulse across D216. This pulse triggers the multivibrator and results in a positive output pulse applied to the base of Q202. This results in a 0.7 volt pulse at the base of Q201 which drives the appropriate indicator.

(b) Multivibrator operation is clamped when a positive voltage is applied to the inhibit transistor Q206. During these periods, no signals will be seen at the base of Q205. The typical waveform across a driver output terminal during a hit is shown in figure 5-1E.

(11) Coincidence Detector. Coincidence between the phase and amplitude hits is detected by the diode "and" gate D209, 210. When a negative hit signal is present at both diode inputs, a negative signal is applied to the coincidence hits driver circuitry. The operation of this driver circuitry is identical to that described in paragraph 5-3c(10).

(12) Dropout Detector. The dropout detector consists of the threshold detector IC207 and the dropout timer IC206A, Q229. A normal level input signal will result in a DC voltage of - 2 volts at the input of the threshold detector. This voltage will drop to near 0 volts when the input signal is removed. When this voltage drops to below the reference voltage set by the dropout detector calibrate control R246, the dropout threshold detector output IC206B pin 7 will change from - 12 to + 12 volts. This change is used to drive the dropout timer which is similar to hit delay circuit of paragraph 5-3c(5) and results in an output signal from IC206B pin 7 which changes from -12 to + 12 volts during a dropout condition. The dropout timer output is also applied to the darlington pair transistors Q225, 226 which drive the dropout indicator lamp.

(13) Caution Detector. The caution detector consists of a diode "or" gate followed by driver circuitry for the CAUTION lamp. It also supplies the positive inhibit voltage to the inhibit transistors located in the amplitude, phase and coincident hit driver circuits. Detection of an out of lock or dropout conditions resuits in a positive output from the appropriate detectors. These outputs are combined by diodes D213, D214, and result in a positive signal applied to the darlington pair transistors Q227, Q228, which drive the CAUTION lamp. The same + 12 volt signal is applied to the inhibit transistors Q206, 212, 218 in the multivibrators.

(14) Power Supply. The power supply consists of a dual tracking +15 regulated supply and an unregulated 28 volt supply. The AC input for the regulated supply should be 32 volts AC as measured across terminals A and B with a multitester. The rectified DC voltages across the filter capacitors C401, 402, should be + 32 volts respectively. If a proper negative output is measured, check the positive voltage regulator Q402, 403, 406, 407. If neither supply voltage is proper, initially check the negative regulator Q401, 404, 405, 408, which supplies the reference voltage to both regulators. If a defective regulator transistor is suspected and the heat sinks of either Q401 and Q402 are cool to the touch replace that regulator transistor. To verify that low voltage operation of the power supply is not the result of current limiting due to excessive load, temporarily disconnect the power supply leads from terminals G and I. Remeasure the supply voltages. If these are normal, connect both supply leads and use an ammeter to measure current output. This should not exceed 160 milliamps. Currents greater than that are the result of problems external to the power supply. If Q401 and 402 are found to be satisfactory, first replace Q404, 405, 408; then, if proper operation is not achieved, replace Q403, 406, 407. Following transistor replacement, reset power supply voltages in accordance with paragraph 5-3d(9). The low voltage AC input to the unregulated 28 volt supply should be 34 volts AC as measured with a multitester between terminals F and E. DC output is 28 _4 volt DC and is measured between terminal D and ground. If the proper DC voltage is not obtained, check for shorts in external wiring and then replace D402.

d. Calibration. The following procedures are used to recalibrate the OUTPUT signal frequency, the input/output level monitor meter, the phase locked oscillator/FREQUENCY meter scale, the peak-to-peak jitter ranges, the phase hits detector, the dropout detector and the out of lock detector. Recalibration is normally required when maintenance has been performed on associated circuitry or when there is a reason to suspect the calibration is no longer accurate.

(1) Test Tone Output Frequency.

Step A. Connect an electronic counter capable of measuring 1020 Hz to the OUTPUT terminals. Adjust the output LEVEL control until the counter is oper.ating consistently. Adjust R361 to give an output frequency of 1020 Hz + 1 Hz.

(2) Input/Output Level Meter.

Step A. Connect the OUTPUT signal terminals to the INPUT terminals. Set the input switch to 600

Step B. Connect a standard reference meter in parallel with the INPUT terminals. Be sure all ground connections are properly made. Set the output level to 0 dBm + 0.1 dB using the reference meter.

Step C. Place the meter switch in the OUTPUT LEVEL position and adjust R393 for a meter reading of 0 dBm ±+0.1 dB.

Step D. Place the meter in the INPUT LEVEL position and adjust R209 to give a meter reading within + 0.1 dB of the reference meter.

(3) Phase Locked Oscillator Frequency/Frequency Meter Scale.

Step A. Connect a 0 dBm test signal at a frequency of 1010 + 1 Hz to the INPUT terminals.

Step B. Monitor the junction of R316, 317, D306, and adjust the phase locked oscillator frequency control R358 to give a perfectly symmetrical square wave, i.e. 50% duty cycle, at this point.

Step C. Change the test signal to a frequency of 990 + 1 Hz. Recalibrate the frequency.

Step D. Adjust the FREQ ZERO control R329 for a meter reading of 990 Hz in the FREQUENCY position of the meter switch.

Step E. Reset the input frequency to 1030 + 1 Hz and adjust the FREQ RANGE control R338 for a meter reading of 1030 Hz.

Step F. Repeat steps C thru E until the proper meter readings are obtained without further adjustment.

(4) Peak-to-Peak Jitter.

Step A. The peak-to-peak jitter ranges are calibrated using a two-tone audio technique where the phase jitter reading is proportional to the level difference between two input signals.

Step B. To perform this calibration, two audio oscillators having 1% or less harmonic distortion are connected using the special test fixtures shown in figure 5-2. A wide variety of integrated circuits or discrete operational amplifiers may be used in the test fixture, including the MC1437L and MC1458G's used in the Model 48. Precision resistors of 1% tolerance are required in these networks. When external amplifier compensation is required, it should be provided for unity gain operation.

Step C. Connect the oscillators as shown to the test fixture, and then connect the test fixture to the in- put of the Model 48. Set the carrier oscillator for a frequency of 1020 Hz (+ 1 cycle) and set its output level to 0 dBm (+ 0.1 dB).

Step D. Adjust the frequency of the sidetone oscillator to 1100 Hz. The output level of this oscillator will be varied to obtain the desired phase jitter calibration levels.

NOTE

Caution must be used in calibrating these low values of phase jitter to ensure that no noise pickup, hum, etc. is introduced by the test fixture.

The carrier oscillator must have a low level of phase jitter in its output. This can be verified by the residual meter reading with the sidetone oscillator disconnected. If this reading is not below 0.15° peak-to-peak, on the 30 range, the carrier oscillator should be replaced with an audio oscillator providing this residual reading. If this cannot be obtained, the OUTPUT oscillator of the Model 48 may be used as the carrier oscillator.

(5) 30° Peak-to-Peak Jitter Range.

Step A. Adjust the LEVEL SET control for a 0 dBm reading in the LEVEL SET meter position.

Step B. Adjust the sidetone oscillator for an output level of - 20 + 0.1 dBm. This setting corresponds to a peak-to-peak jitter level of 11.50.

Step C. Adjust R341 to give a reading of 11.5°.

(6) 3° Peak-to-Peak Jitter Range.

Step A. Set the meter switch in the 30 P-P Jitter range.

Step B. Adjust the sidetone oscillator for a level of -41.2 _+0.1 dB. This corresponds to a peak-to-peak jitter value of 1.0°.

Step C. Adjust the 30 calibration control R342 for this meter reading.

(7) Phase Hits Detector.

Step A. Calibration of the phase hits detector is made in a similar manner to that of the phase jitter calibration using the test fixtures of Figure 5-2.

Step B. Repeat Steps A through D of paragraph 5-3d(4).

Step C. Place the PEAK DEGREE switch in the 15° position and place the timer in the HOLD position.

Step D. Adjust the sidetone oscillator for a level of -11.74 + 0.1 dB.

Step E. Place the HIT DELAY switch in the OUT position, and the FLASH/COUNT switch in the COUNT position.

Step F. Adjust R388 so the PHASE HITS totalizer just begins to count with a steady rhythm. Verify that counter operation can be halted by a slight adjustment of R388, and then reset to the steady counting position.

(8) Dropout Threshold.

Step A. Adjust the instrument in accordance with information in Paragraph 5.2.2.

Step B. Without readjusting the LEVEL SET control, lower the input level 12.0 dB. An external level meter should be used to obtain accurate readings of the output level.

Step C. Adjust the dropout calibrate control R246 to just extinguish the CAUTION light. This light should again illuminate when the input level is dropped an additional 0.5 dB.

(9) Out of Lock Detector.

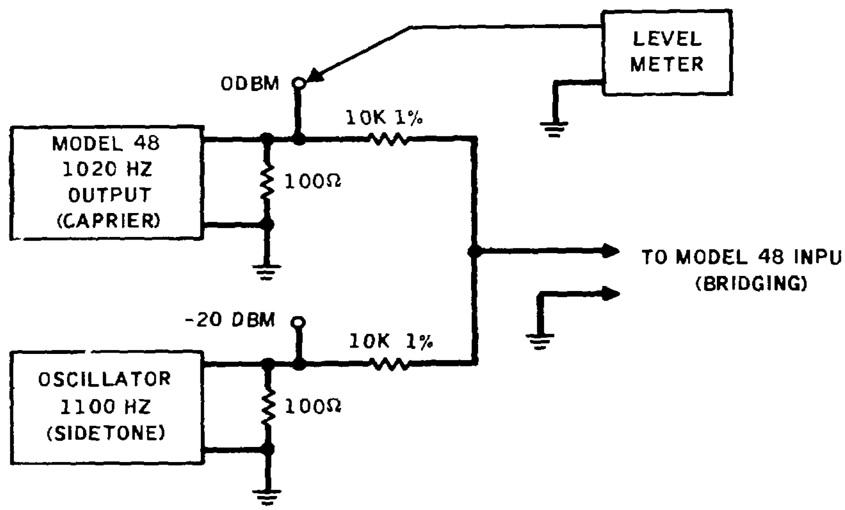
Step A. Connect a 0 dBm 985 Hz signal to the INPUT terminals.

Step B. Adjust the CAUTION FREQ control R320 to just illuminate the CAUTION light.

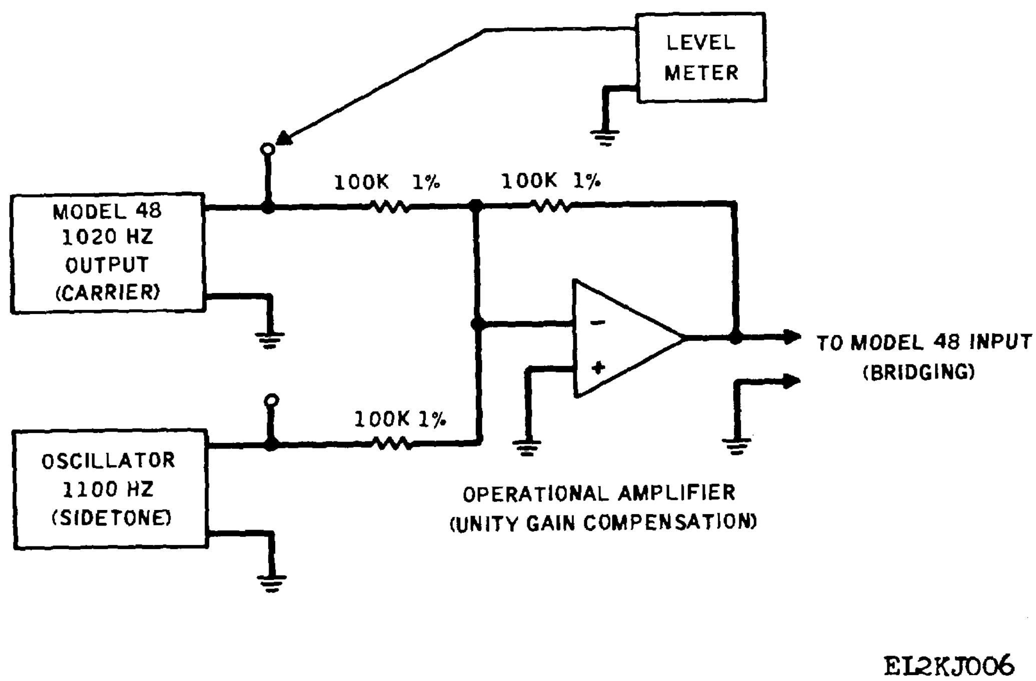
Step C. Slowly increase the input frequency to extinguish the CAUTION light and continue until the CAUTION light again illuminates. This frequency should be between 1030 and 1050 Hz. (10) Power Supply Voltage.

Step A. Connect an accurate DC voltmeter be tween terminals H and I of the power supply. Adjust R416 for - 15.0 volts.

Step B. Move the DC voltmeter to terminals H and G and adjust R417 for an output of + 15.0 volts DC.



A. RESISTOR TEST JIG (11.5 P-P JITTER ONLY)



B. OPERATIONAL AMPLIFIER TEST JIG

Figure 5-2. Phase Jitter Calibration Test Jigs

Table 5-3. Phase Jitter Calibration Chart

Sidetone level	Peak-to-peak jitter	Application
- 11.7dB	30°	Phase hit calibration point (150 Peak Degrees)
- 20.0 dB	11.5°	300 P-P JITTER range calibration point
- 41.2 dB	1.0°	30 P-P JI'I7ER range calibration point

NOTE: Carrier oscillator is set at 0.0 dBm.

Table 5-4. Model 48 Main Frame Parts List

Fig No	Ref No	Description	Part No	Mfr.
	DS101 thru DS107	Pilot Lamp 28v, .040 amps	327	
	F101	Fuse, 12 amp, 250v, slow blow		
	J101 thru J103	Binding Post	29-1	Grayhill
	J104	Phonejack, 3 circuit	#12B	Switchcraft
	J105 thru J107	Same as J101		
	J108 thru J110	Same as J104		
	J111 thru J114	BNC Connector	UGI109AIU	Amphenol
	J115	A/C Receptacle	160-5	Amphenol
	L101	Holding Coil	C1709	Stancor
	L 102 thru L105	Counter, 24vdc, 4 digit	RG141E	Sodeco
	M101io	Meter, 0-50 microamp	44-039	HLI
	R101	Resistor, Fixed 604ohm, 1%	RN70D	Corning
	R102	Resistor, Fixed 909ohm, 1%	RN70D	Corning
	R103	Resistor, Variable 10K	WA2605	A. B.
	R104 thru R112	Resistor, Fixed 150ohm, + 1%, /4W	RN55D	
	R113	Resistor, Fixed 412ohm, ± 1%, /4W	RN55D	
	R114	Resistor, Fixed 464ohm, + 1%, '/4W	"	
	R115	Resistor, Fixed 1740ohm, + 1%, /4W	"	
	R116	Resistor, Fixed294ohm, +1%, '/4W	"	
	R117	Resistor, Fixed 261ohm, ± 1%, 1/4W	"	
	R118	Resistor, FixedJ6190hm, 1%, /W	"	
	R119	Resistor, Fixed 1500ohm, + 1%, '/W4	"	
	R120	Resistor, Variable lOK	WA2032P	A. B.
	R121	Resistor, Fixed, 137ohm, 1%	RN70D	Corning
	S101	Switch, Rocker, 2 pole, 2 position	5201-B788-2	C-K
	S102	Switch, Rotary, 5 pole, 6 position	5-27551-31	Marco-Oak
	S103	Switch, Rotary, 1 pole, 9 position	5-12221-312	Marco-Oak
	S104	Switch, Rotary, 2 pole, 4 position	5-15731-312	Marco-Oak
	S105	Switch, Rotary, 3 pole, 4 position	3RB4	ALCO
	S106	Switch, Toggle, 4 pole, 2 position	JMT-423	JBT
	S107	Switch, Rotary, 3 pole, 3 position	MRA-3-3S	Alco
	S108	Switch, Timer, 60 min with hold	90024	M. H. Rhodes
	S109	Switch, Slide, 2 Pole, 2 Position	20637	C-W
	T101	Transformer	44-018	HLI

Table 5-5. HL148-200 Board Parts List

Fig.No	Ref.No	Description	Part No	Mfr.
	C201	Capacitor, Fixed, .039 Mfd, 5%, 200v	MWR	Standard
	C202	Same as C201		
	C203	Capacitor, Fixed, .047 Mfd, 2.5%, 33v	611	Mial
	C204	- 022 , Mfd, 2.5%, 33v	"	"
	C205	" ",.0033 Mfd, 2.5%,,-33v	"	"
	C206	" ",.1 Mfd, 5%, l00v	B32541	Siemans
	C207	" ",.068 Mfd, 2.5%, 33v	611	Mial
	C208	"i ,.0027 Mfd, 2.5%,33v	611	Mial
	C209	Capacitor, Fixed,.22 Mfd, 5%, lOOv	B32541	Siemans
	C210	Capacitor, Electrolytic, 22 Mfd, 10%	CS13B	
	C211	Same as C207		
	C212	Capacitor, Fixed, .039 Mfd, 2.5%,33v	611	Mial
	C213	Capacitor, Fixed, .0075 Mfd, 2.5%, 33v	611	Mial
	C214	Same as C207		

Table 5-5. HLI48-200 Board Parts List (Continued)

Fig. No	Ref. No	Description	Part No	Mfr.
	C215	Capacitor, Fixed, .0022 Mfd, 2.5%, 33v	611	Mial
	C216 thru C218	Capacitor, Ceramic 10 pfd, NPO	10TCC	Sprague
	C219 thru C221	Capacitor, Ceramic, 3.3 pfd, NPO	10TCC	Sprague
	C222	Same as C209		
	C223 thru	SameasC210		
	C224	Capacitor, Electrolytic, 1.0 Mfd, 10%, 35v	CS13B	
	C225	Same as C216		
	C226	Same as C219		
	C227	Capacitor, Electrolytic, 50 Mfd, 35v	TAD	2EC
	C228	Capacitor, Ceramic, .001 Mfd	Z5U	
	C229	Same as C209		
	C230 A,B,C	Same as C228		
	C231 A,B,C	SameasC209		
	C232, C233	Capacitor, Ceramic, .lmfd,+80%, -20%,20v	UK20-104	Central Lab
	D201 thru	Diode, Silicon	IN3064	
	D216 A,B,C			
	D217 A,B,C			
	D218			
	IC201 thru IC204	Integrated Circuit	RC4558 or equal	Raytheon
	IC205, IC206	Integrated Circuit	MC1437 or equal	Motorola
	IC207	Same as IC 201		
	Q201	Transistor, Silicon	2N3440	
	Q202, Q203	Transistor, Silicon	2N3566	
	Q204	Transistor, Silicon	2N5138	
	Q205, Q206	Same as Q202		
	Q207 '	SameasQ201		
	Q208, Q209	Same as Q202		
	Q210	Same as Q204		
	Q211, Q212	Same as Q202		
	Q213	SameasQ201		
	Q214,Q215	Same as Q202		
	Q216	SameasQ204		
	Q217, Q218	Same as Q202		
	Q219	SameasQ201		
	Q220, Q221	Same as Q202		
	Q222	Same as Q204		
	Q223	Same as Q202		
	Q224	Same as Q204		
	Q225	Same as Q202		
	Q226	Same as Q201		
	Q227	SameasQ202		
	Q228	Sameas Q201		
	Q229, Q230	Same as Q204		
	R201	Resistor, Fixed 15K, _ 5%, 2W	RCR07	A. B.
	R202	Resistor, Fixed 4,02K, + 1%	RN55D	
	R203	Resistor, Fixed 8.06K, + 1%		
	R204	Resistor, Fixed 3.48K, ± 1%		
	R205	Resistor, Fixed 24.3K, + 1%		
	R206	Resistor, Fixed 7.32K,1%		
	R207	Resistor, Fixed 4.32K, ± 1%		
	R208	Resistor, Fixed 10.5K, ± 1%		
	R209	Resistor, Variable 1K, 10%, MW	72PMR2K	Helipot
	R210	Resistor, Fixed O10K, + 5%, /4W	RCR7	A. B.
	R211	Resistor, Fixed 2.2K, _5%, /4W		A. B.
	R212	Resistor, Fixed 22ohm, ± 5%, 1/4 W		A. B.
	R213	Resistor, Fixed 20K, ± 1%	RN55D	
	R214 thru R217	Resistor, Fixed O10K, + 1%	RN55D	
	R218,R219	Resistor, Fixed 4.7K, ± 5%, /W	RCR07	A. B.
	R220	Resistor, Fixed 31.6K, 1%	RN55D	
	R221, R222	Resistor, Fixed 20.5K, ± 1%	RN55D	
	R223	Resistor, Fixed 12.1K,1%	"	
	R224	Resistor, Fixed 41.2K,5%,W	"	A. B.
	R225	Resistor, Fixed 22K, +-5%, 1/4W	RCR07	A. B.

Table 5-5. HL 48-200 Board Parts List (Continued)

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R226	Resistor, Fixed 31.6K, ± 1%	RN55)	
	R227	Resistor, Fixed 63.4K, ± 1%	RN55D	
	R228	Resistor, Fixed 21.5K, ± 1%	RN55D	
	R229	Resistor, Fixed 47K, t 5%, I/W	RCRO7	A. B.
	R230	Resistor, Fixed 7.5K, 5%, I W	RCRO7	A. B.
	R231	Resistor, Fixed 365Q _ 1%	RN55D	
	R232	Resistor, Fixed 324Q + 1%	RN55D	
	R233, R234	Same as R218		
	R235, R236	Resistor, Fixed 2.2M, + 5%, I/W	RCR07	A. B.
	R237	SameasR218		
	R238	Resistor, Fixed 22K, + 5%, / W	RCR07	A. B.
	R239	SameasR225		
	R240	Resistor, Fixed 0lohm, ± 5%, /W	RCR07	A. B.
	R241,R242	SameasR210		
	R243	Resistor, Fixed 100K, ± 5%, /4W	RCR07	A. B.
	R244	Same as R229		
	R245	Resistor, Fixed, 22.1K, t 1%	RN55D	
	R246	Resistor, Variable, 1K, ± 10%	72PMR1K	Helipot
	R247	Resistor, Fixed, 1K, ± 5%, I/ w	RCRO7	A. B.
	R248	SameasR235		
	R249	Same as R211		
	R250	SameasR218		
	R251	Resistor, Fixed, 13K, ± 5%, 1W	RCR07	A. B.
	R252	Same as R240		
	R253	Same as R243		
	R254 thru R258	Same as R210		
	R259 thru R262	Resistor, Fixed, 33K, ± 5%, /4w	RCR07	A. B.
	R263 thru R265	Same as R218		
	R266,R267	Same as R225		
	R268	Same as R229		
	R269	Same as R259		
	R270	Same as R229		
	R271	Resistor, Fixed 200K, +5%, I/W	RCR07	A, B.
	R272	Resistor, Fixed 6.8K, 6 5%, /4W	RCR07	A. B.
	R273	Same as R239		
	R274	Resistor, Fixed, 1K, ± 5%, 'bw	RCR07	A. B.
	R275	SameasR211l		
	R276	Resistor, Fixed 120K, 5%, I/W	RCR07	A. B.
	R277A,B,C	SameasR225		
	R278A,B,C			
	R279 A, B, C	Same as R271		
	R280 A, B, C	Same as R272		
	R281 A, B, C	Same asR229		
	R282 A,B, C			
	R283 A, B, C	Same as R211		
	R284 A, B, C	Same as R263		
	R285A,B,C	SameasR274		
	R286 A, B, C	Same as R210		
	R287 A, B, C	Same as R259		
	R288	Same as R229		
	R289	Resistor, Fixed, 2.2K, 5%, /4w	RCR07	A. B.
	R290	Resistor, Fixed, 10K, 5%, /w	RCR07	A. B.
	T201	Transformer	BUG 4-2	ADC

Table 5-6. HLI48-300 Board Parts List

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	C301, C302	Capacitor, Ceramic 3.3 pfd NPO	10TCC	Sprague
	C303 thru C305	Capacitor, Ceramic 10 pfd NPO	10TCC	Sprague
	C307	Capacitor, Ceramic, 1.0 mfd, 50v	5C023105X-0500B3	Sprague
	C306	Same as C301		
	C308	Capacitor, Fixed, .013 mfd, ± 2.5%, 33v	611	Mial
	C309	Capacitor, Fixed, .0075 mfd, ± 2.5%, 33v	“	“
	C310, C311	Capacitor, Fixed, .039 mfd, ± 2.5%, 33v	“	“
	C312	Capacitor, Fixed, .068 mfd, ± 2.5%, 33v	“	“
	C313	Capacitor, Fixed, .001 mfd, ± 2.5%, 33v	“	“
	C314, C315	Capacitor, Fixed, .47 mfd, ± 5%, 100v	B32541	Siemans
	C316	Not used		
	C317 thru C, 319	Capacitor, Electrolytic, 22 mdf	150D	Sprague
	C320	Capacitor, Fixed, 390 pfd, ± 5%, 500v	CM05	
	C321, C322	Capacitor, Fixed, .10 mfd, ± 2.5%, 33v	611	Mial
	C323	Same as C301		
	C324	Same as C303		
	C325	Capacitor, Ceramic, .01 mfd		Z5U
	C326	Capacitor, Fixed, .01 mfd, 2.5%, 33v		611 Mial
	C327	Capacitor, Fixed, 5 mfd, 10%, 200v		M2W-F
	Standard			
	C328	Same as C326		
	C329, C330	Not used		
	C331, C332	Capacitor, Ceramic, .1mfd, +80%, -20%, 20v	UK20-104	Central Lab
	C333 thru C336	Capacitor, Ceramic, 47 pf, NPO	10TCC	Sprague
	C337, C338	Capacitor, Fixed, .22 mfd, 5%, 100v	B32541	Siemans
	C339	Capacitor, Electrolytic, 50 mfd, 35v	TAD	IEC
	C340	Same as C337		
	D301 thru D305	Diode, Silicon	1N3064	Fairchild
	D306, D307	Diode, Zener	1N5731B	Amperex
	D308 thru D313	Same asD301		
	D314, D315	Diode, Germanium	1N191	GE
	D316, D317	Same asD301		
	IC301, IC302	Integrated Circuit	MC1437L or equal	Motorola
	IC303 thru IC305	Integrated Circuit	MC1458G or equal	Motorola
	IC306	Same as IC301		
	IC307, 308, 309	Same as IC303		
	Q301 thru Q307	Transistor, Silicon	2N3566	Fairchild
	Q308 thru Q310	Transistor, Silicon	2N5138	Fairchild
	Q311, Q312	Same as Q301		
	R301 thru R304	Resistor, Fixed 10K, ± 5%, 114W	RCR07	A. B.
	R305	Resistor, Fixed 22K, ± 5%, 1/4W	RCR07	A. B.
	R306 thru R311	Resistor, Fixed 100K, ± 5%, 1/4W		A. B.
	R312 thru R315	Same asR301		
	R316	Same as R305		
	R317	Resistor, Fixed, 2.2K ± 5%, 1/4w	RCR07	A. B.
	R318, R319	Resistor, Fixed, 220K, ± 5%, 1/4w	RCR07	A. B.
	R320	Resistor, Variable, 20K, ± 10%	89PR20K	Helipot
	R321	Resistor, Fixed, 1K, ± 5%, 1/4W	RCR07	A. B.
	R322	Resistor, Fixed, 100K, +5%	RCR07	A. B.
	R323 thru R325	Resistor, Fixed, 32, 4K, ± 1%	RN55D	
	R326	Same asR301		
	R327	Resistor, 9019K, ± 1%	RN55D	
	R328	Resistor, 21.5K, ± 1%	RN55D	
	R329	Resistor, Variable, 10K, ± 10%	72PMR10K	Helipot
	R330	Resistor, Fixed, Selected Value	RN55D	
	R331	Resistor, Fixed, 68.1K, ± 1%	RN55D	
	R332	Resistor, Fixed, 31.6K, ± 1%	RN55D	
	R333	Resistor, Fixed, 90.9K, ± 1%	RN55D	
	R334	Resistor, Fixed, 100 ohm, ± 5%, 114w	RCR07	A. B.
	R335	Resistor, Fixed, 27.4K, ± 1%	RN55D	
	R336	Same as R305		
	R337	Resistor, Fixed, 31.6K, ± 1%	RN55D	
	R338	Resistor, Variable, 50k, ± 10%	72PMR50K	Helipot
	R339	Resistor, Fixed, 10K, ± 1%	RN55D	

Table 5-6. HLI48-300 Board Parts List (Continued)

Fig. No.	Ref. No.	Description	Part No.	Mfr.
	R340	Resistor, Fixed, 4.7K, ± 5%, 1/4w	RCR07	A. B.
	R341, R342	Resistor, Variable, 20K, ± 10%	89PR20K	Helipot
	R343, R344	Same as R322		
	R345	Resistor, Fixed, 61.9K, ± 1%	RN55D	
	R346	Resistor, Fixed, 54.9K, ± 1%	RN55D	
	R347	Resistor, Fixed, 2.74K, ± 1%	RN55D	
	R348	Resistor, Fixed, 18.2K, ± 1%	RN55D	
	R349, R350	Same as R301		
	R351	Resistor, Fixed, 51.1K, ± 1%	RN55D	
	R352	Resistor, Fixed, 182K, ± 1%	RN55D	
	R353	Resistor, Fixed, 225K, ± 1%	RN55D	
	R354	Resistor, Fixed, 1.0M, ± 5%, 114w	RCR07	A. B.
	R355	Same as R301		
	R356	Resistor, Fixed, 31.6K, ± 1%	RN55D	
	R357	Resistor, Fixed, 86.6 ohm, ± 1%	RN55D	
	R358	Resistor, Variable 500 ohm, ± 10%	89PR500Helipot	
	R359	Same as R321		
	R360	Resistor, Fixed, 14.7K, ± 1%	RN55D	
	R361	Resistor, Variable, 2K, ± 10%	72PMR2K	Helipot
	R362, R363	Resistor, Fixed, 10K, ± 1%	RN55D	
	R364	Resistor, Fixed, 15.4K, ± 1%	RN55D	
	R365	Same as R305		
	R366	Same asR354		
	R367	Resistor, Fixed, 10K, ± 5%, 114w	RCR07	A. B.
	R368	Resistor, Fixed, 24K, ± 5%, 114w	RCR07	A. B.
	R369	Resistor, Fixed, 511 ohm, ± 1%	RN55D	
	R370	Resistor, Fixed, 1.62K, ± 1%	RN55D	
	R371 thru R374	Same as R339		
	R375	Resistor, Fixed, 20K, ± 1%	RN55D	
	R376	Resistor, Fixed, 16.2K, ± 1%	RN55D	
	R377, R378	Same as R340		
	R379, R380	Same as R321		
	R381	Resistor, Fixed, 2.2M, ± 5%, 1/4w		A. B.
	R382, R383	Same as R336		
	R384	Same as R334		
	R385, R386	Same as R301		
	R387	Same as R322		
	R388	Resistor, Variable, 1K, ± 10%	89PR1K	Helipot
	R389	Resistor, Fixed, 1.2K, ± 5%, 114w	RCR07	A. B.
	R390, R391	Same as R339		
	R392	Not used		
	R393	Resistor, Fixed, 11.5K, ± 1%	RN55D	
	R394	Resistor, Fixed, 9.09K, ± 1%	RN55D	
	R395	Resistor, Variable, 2K, ± 10%	72PMR2K	Helipot
	R396	Resistor, Fixed, 9.09K, ± 1%	RN55D	A. B.
	T301	Audio, Transformer	11475	HLI

Table 5-7. Power Supply Parts List.

Fig. No.	Ref. No.	Description	Part No.	Mfr.
5-7	C401, 402	Capacitor, Electrolytic, 330 mfd, 35 vdc	TAD	IEC
	C403	Capacitor, Paper, .22 mfd	225P	Sprague
	C404, 405	Capacitor, Ceramic, 200 pfd, 10%	Z5U	Sprague
	C406, 407	Capacitor, Electrolytic, 50 mfd, 35 vdc	TAD	IEC
	D401, 402	Full Wave Bridge Silicon Rectifier	FW-100	Mallory
	D403, 404	Diode, Silicon	1N4002	Fairchild
	D405	Diode, Zener	1N751A	GE
	D406 thruD410	Diode, Silicon	1N3064	Fairchild
	R401, 402	Resistor, Fixed, 2.4 ohm, 5%, 1/2w	RCR07	A. B.
	R403, 404	Resistor, Fixed, 47 ohm, 5%, 1/4w	RCR07	A. B.
	R405, 406	Resistor, Fixed, 1k, 5%, 1/4w		
	R407, 408	Resistor, Fixed, 1.5k, 5%, 1/4w		
	R409	Resistor, Fixed, 820 ohm, 5%, 1/4w		
	R410	Resistor, Fixed, 15k, 5%, 1/4w		
	R411	Resistor, Fixed, 22k, 5%, 1/4w		
	R412	Resistor, Fixed, 680K, 5%, 1/4w		
	R413	SameasR410		
	R414	Resistor, Fixed, 1k, 1%, 1/4w	RN60D	
	R415	Resistor, Fixed, 1.82k, 1%, 1/4w	RN60D	
	R416, 417	Resistor, Variable, 1k, 10%, 1/2w	72WR1K	Helipot
	R418	Resistor, Fixed, 4.75k, 1%, 1/4w	RN60D	
	R419	Resistor, Fixed, 5.11k, 1%, 1/4w	RN60D	
	Q401	Transistor, Silicon	62203	RCA
	Q402	Transistor, Silicon	62204	RCA
	Q403	Transistor, Silicon	2N5138	
	Q404, 405	Transistor, Silicon	2N3566	
	Q406	Same as Q403		
	Q407	Same as Q404		

APPENDIX A

REFERENCES

DA Pam 310-4	Index of Technical Manuals, Technical Bulletins Supply Manuals (Types 7, 8, and 9), Supply Bulletins and Lubrication Orders.
DA Pam 310-7	US Army Equipment Index of Modification Work Orders.
TB 43-180	Calibration Requirements for the Maintenance of Army Materiel.
TM 11-6625-683-15	Operator's Organizational, Direct Support, General Support and Depot Maintenance Manual, Signal Generator ANI/URM-127 (NSN 6625-00-783-5965).
TM 11-6625-654-14	Operator's, Organizational, Direct Support, and General Support Maintenance Manual (Including Repair Parts and Special Tools List) for Multimeter, AN/USM-223.
TM 11-6625-2658-14	Operator's Organizational, Direct Support, and General Support Maintenance Manual for Oscilloscope, ANIUSM-281C.
TM 38-750	The Army Maintenance Management System (TAMMS).
TM 750-244-2	Procedures for Destruction of Electronics Materiel to Prevent Enemy Use (Electronice Command).

APPENDIX B

MAINTENANCE ALLOCATION

Section I. INTRODUCTION

B-1. General

This appendix provides a summary of the maintenance operations for the ME-490/U. It authorizes categories of maintenance for specific maintenance functions on repairable items and components and the tools and equipment required to perform each function. This appendix may be used as an aid in planning maintenance operations.

B-2. Maintenance Function

Maintenance functions will be limited to and defined as follows:

a. Inspect. To determine the serviceability of an item by comparing its physical, mechanical, and/or electrical characteristics with established standards through examination.

b. Test. To verify serviceability and to detect incipient failure by measuring the mechanical or electrical characteristics of an item and comparing those characteristics with prescribed standards.

c. Service. Operations required periodically to keep an item in proper operating conditions, i.e., to clean (decontaminate), to preserve, to drain, to paint, or to replenish fuel, lubricants, hydraulic fluids, or compressed air supplies.

d. Adjust. To maintain, within prescribed limits, by bringing into proper or exact position, or by setting the operating characteristics to the specified parameters.

e. Align. To adjust specified variable elements of an item to bring about optimum or desired performance.

f. Calibrate. To determine and cause corrections to be made or to be adjusted on instruments or test measuring and diagnostic equipment used in precision measurement. Consists of comparisons of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared.

g. Install. The act of emplacing, seating, or fixing into position an item, part, module (component or assembly) in a manner to allow the proper functioning of the equipment or system.

h. Replace. The act of substituting a serviceable like type part, subassembly, or module (component or assembly) for an unserviceable counterpart.

i. Repair. The application of maintenance services (inspect, test, service, adjust, align, calibrate, replace) or other maintenance actions (welding, grinding, riveting, straightening, facing, re-machining, or resurfacing) to restore serviceability to an item by correcting specific damage, fault, malfunction, or failure in a part, subassembly, module (component or assembly), end item, or system.

j. Overhaul. That maintenance effort (service/action) necessary to restore an item to a completely serviceable/operational condition as prescribed by maintenance standards (i.e., DMWR) in appropriate technical publications. Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like new condition.

k. Rebuild. Consists of those services actions necessary for the restoration of unserviceable equipment to a like new condition in accordance with original manufacturing standards. Rebuild is the highest degree of materiel maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours, miles, etc.) considered in classifying Army equipment/components.

B-3. Column Entries

a. Column 1, Group Number. Column 1 lists group numbers, the purpose of which is to identify components, assemblies, subassemblies, and modules with the next higher assembly.

b. Column 2, Component/Assembly. Column 2 contains the noun names of components, assemblies, sub-assemblies, and modules for which maintenance is authorized.

c. Column 3, Maintenance Functions. Column 3 lists the functions to be performed on the item listed in column 2. When items are listed without maintenance functions, it is solely for purpose of having the group numbers in the MAC and RPSTL coincide.

d. Column 4, Maintenance Category. Column 4 specifies, by the listing of a "worktime" figure in the appropriate sub-column(s), the lowest level of maintenance authorized to perform the function listed in column 3. This figure represents the active time required to perform that maintenance function at the indicated category of maintenance. If the number or complexity of the tasks within the listed maintenance function vary at different maintenance categories, appropriate 'worktime" figures will be shown for each category. The number of task-hours specified by the "worktime" figure represents the average time required to restore an item (assembly, subassembly, component, module, end item or system) to a serviceable condition under typical field operating conditions. This time includes preparation time, troubleshooting time, and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the maintenance allocation chart. Sub-columns of column 4 are as follows:

C-Operator/Crew
O-Organizational
F-Direct Support
H-General Support
D-Depot

e. Column 5, Tools and Equipment. Column 5 specifies by code, those common tool sets (not individual tools) and special tools, test, and support equipment required to perform the designated function.

f. Column 6, Remarks. Column 6 contains an alphabetic code which leads to the remark in section IV, Remarks, which is pertinent to the item opposite the particular code.

B-4. Tool and Test Equipment (Sec III)

a. Tool or Test Equipment Reference Code. The numbers in this column coincide with the numbers used in the tools and equipment column of the MAC. The numbers indicate the applicable tool or test equipment for the maintenance functions.

b. Maintenance Category. The codes in this column indicate the maintenance category allocated the tool or test equipment.

c. Nomenclature. This column lists the noun name and nomenclature of the tools and test equipment required to perform the maintenance functions.

d. National/NATO Stock Number. This column lists the National/NATO stock number of the specified tool or test equipment.

e. Tool Number. This column lists the manufacturer's part number of the tool followed by the Federal Supply Code for manufacturers (5-digit) in parentheses.

B-5. Remarks (Sec IV)

a. Reference Code. This code refers to the appropriate item in section II, column 6.

b. Remarks. This column provides the required explanatory information necessary to clarify items appearing in section II.

SECTION II. MAINTENANCE ALLOCATION CHART
FOR
PHASE JITTER METER ME-490/U

(1) GROUP NUMBER	(2) COMPONENT ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQUIPMENT	(6) REMARKS
00	Phase Jitter Meter, ME-490/U	Inspect		.5				9	A and B
		Test				.8		1 through 8	
C									
		Service				1.0		1 through 8	D
		Adjust				1.0		1 through 8	
D									
		Repair				2.0		1 through 8	
D									
		Overhaul					5.0	1 through 8	
D									
		Calibrate				3.0	3.0	1 through 8	
D									

SECTION III. TOOL AND TEST EQUIPMENT REQUIREMENTS FOR PHASE JITTER METER, ME-490/U

(1) TOOL OR TEST EQUIPMENT REF CODE	(2) MAINTENANCE LEVEL	(3) NOMENCLATURE	(4) NATIONAL/NATO STOCK NUMBER	(5) TOOL NUMBER
1	H, D	Variable Transformer, CN-16/U	5950-00-235-2086	
2	H, D	Audio Oscillator, AN/URM 127 (HP 204C SG-967/U (p/o AN/USM-181 SG-543 HP-3550)	6625-00-783-5965 4935-00-153-7319	
3	H, D	AC Voltmeter, ME-459/U (HP 400 EL)	6625-00-229-0457	
4	H, D	Oscilloscope, AN/USM-281C (HP 180D)	6625-00-105-9622 6625-00-022-8228	
5	H, D	Multimeter, AN/USM-223 (Simpson 260-6)	6625-00-999-7465 6625-00-238-1274	
6	H, D	Test Set, Semiconductor, TS-1836D/U	6625-00-376-1662	
7	H, D	Calibration test jig (Refer to section 5.3.4.5		
8	H, D	Tool Kit, TK-100/U	5180-00-605-0079	
9	O	Tools and test equipment available to the organization repair mission for the assigned mission		

SECTION IV. REMARKS

Reference Code	Remarks
A	Visual (External)
B	Replace fuses, knobs, etc.
C	Performance tests only.
D	All

* U.S. GOVERNMENT PRINTING OFFICE : 1992 - 311-831 (60884)

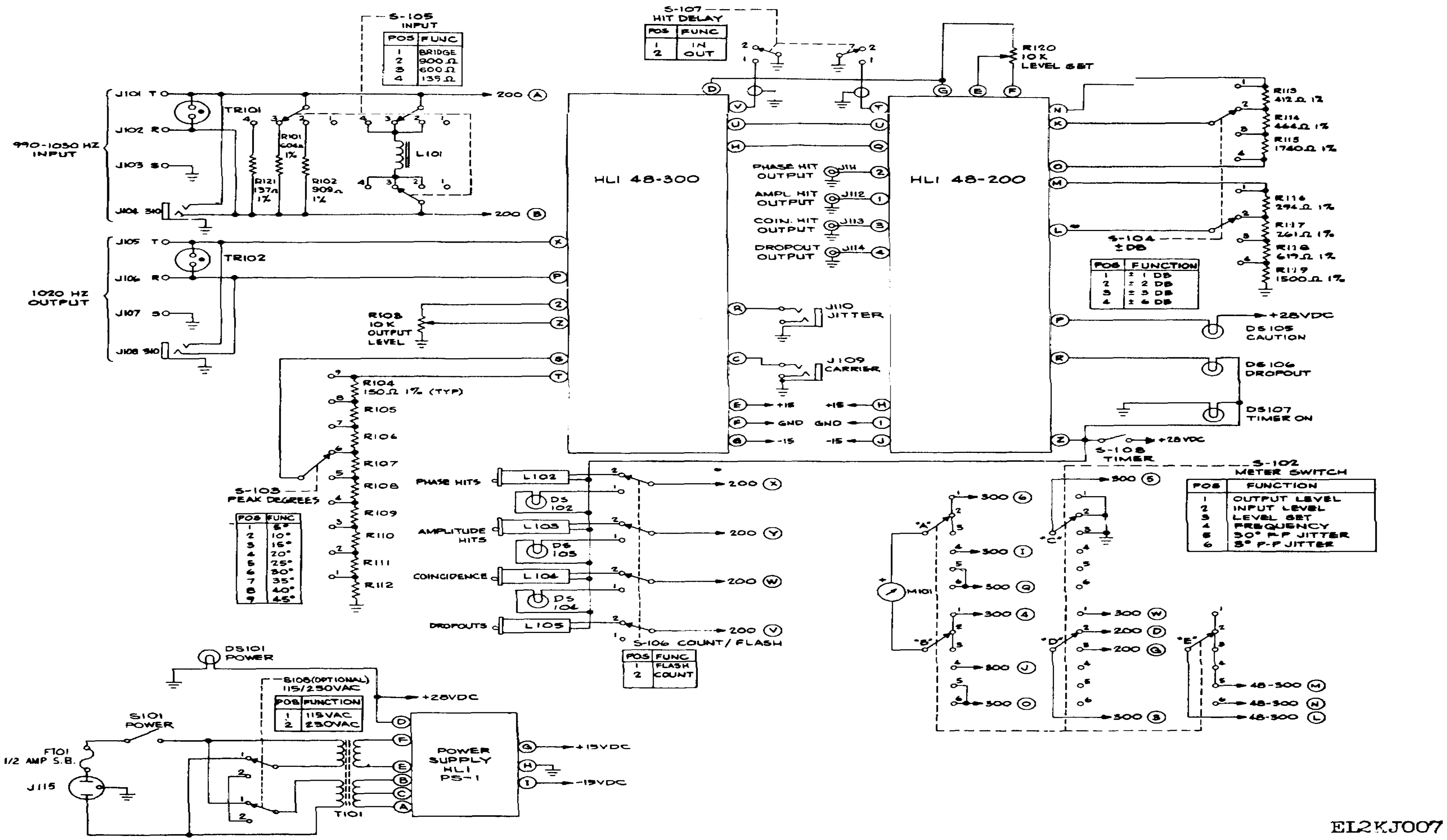


Figure 5-3. MAINFRAME SCHEMATIC DIAGRAM

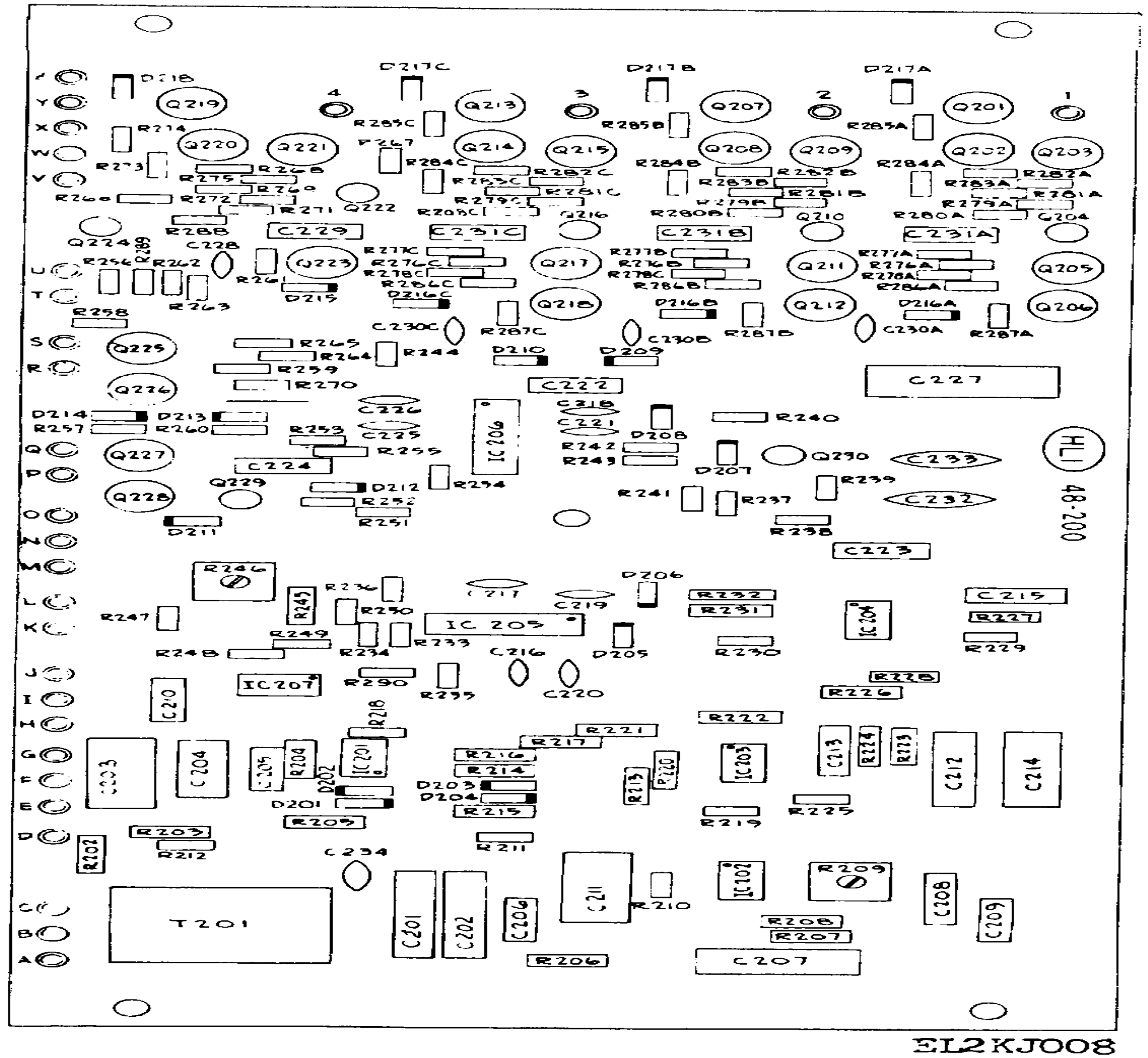


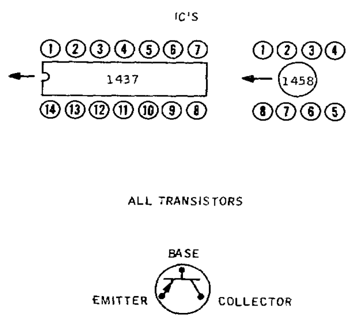
Figure 5-4. HLI 48-200 P.C. BOARD COMPONENT LAYOUT

NOTES

1. TYPE 1437 IC'S HAVE -15V DC ON PIN 7 AND +15V DC ON PIN 14
2. TYPE 1458 IC'S HAVE -15V DC ON PIN 4 AND +15V DC ON PIN 8
3. ALL UNMARKED CAPACITY VALUES IN MFD
4. ALL UNMARKED DIODES ARE TYPE IN3064

* SELECTED VALUE

PIN DIAGRAMS - BOTTOM VIEW



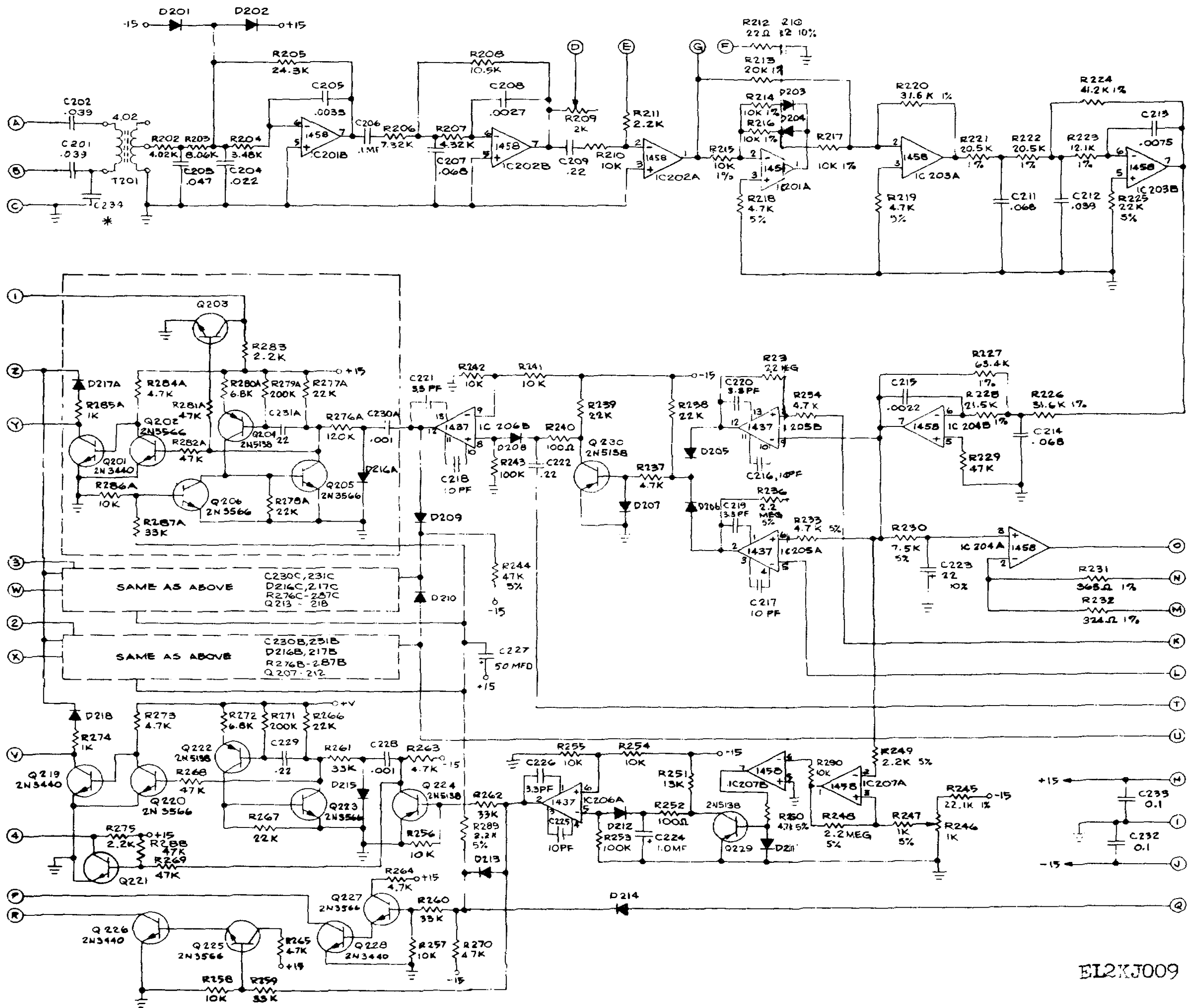


Figure 5-5. HLI 48-200 P.C. BOARD SCHEMATIC DIAGRAM

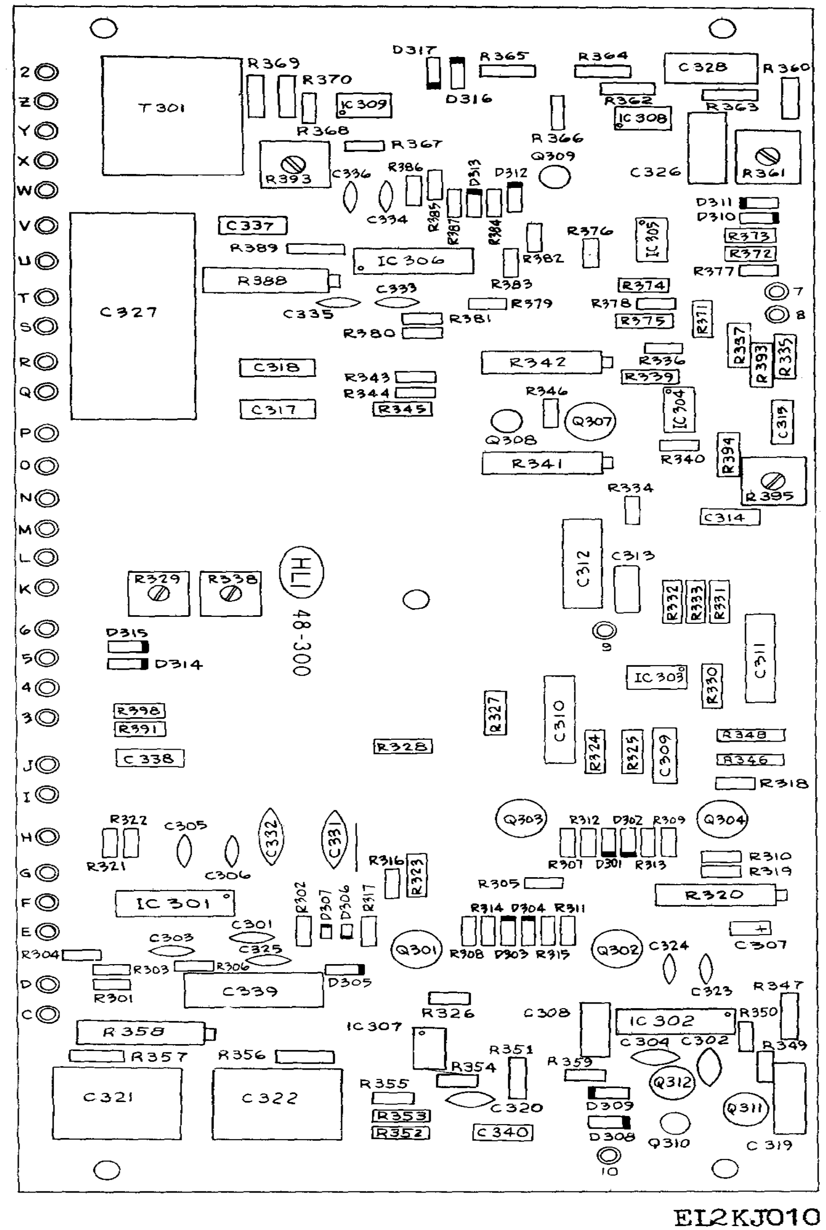
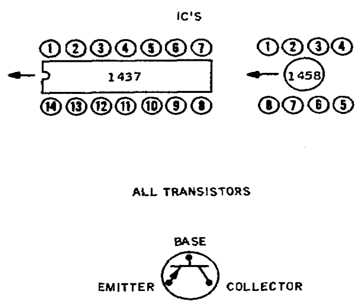


Figure 5-6. HLI 48-300 P.C. BOARD COMPONENT LAYOUT

NOTES

1. TYPE 1437 IC'S HAVE -15V DC ON PIN 7 AND +15V DC ON PIN 14
2. TYPE 1458 IC'S HAVE -15V DC ON PIN 4 AND +15V DC ON PIN 8
3. ALL UNMARKED CAPACITY VALUES IN MFD
4. ALL UNMARKED DIODES ARE TYPE IN3064
* SELECTED VALUE

PIN DIAGRAMS - BOTTOM VIEW



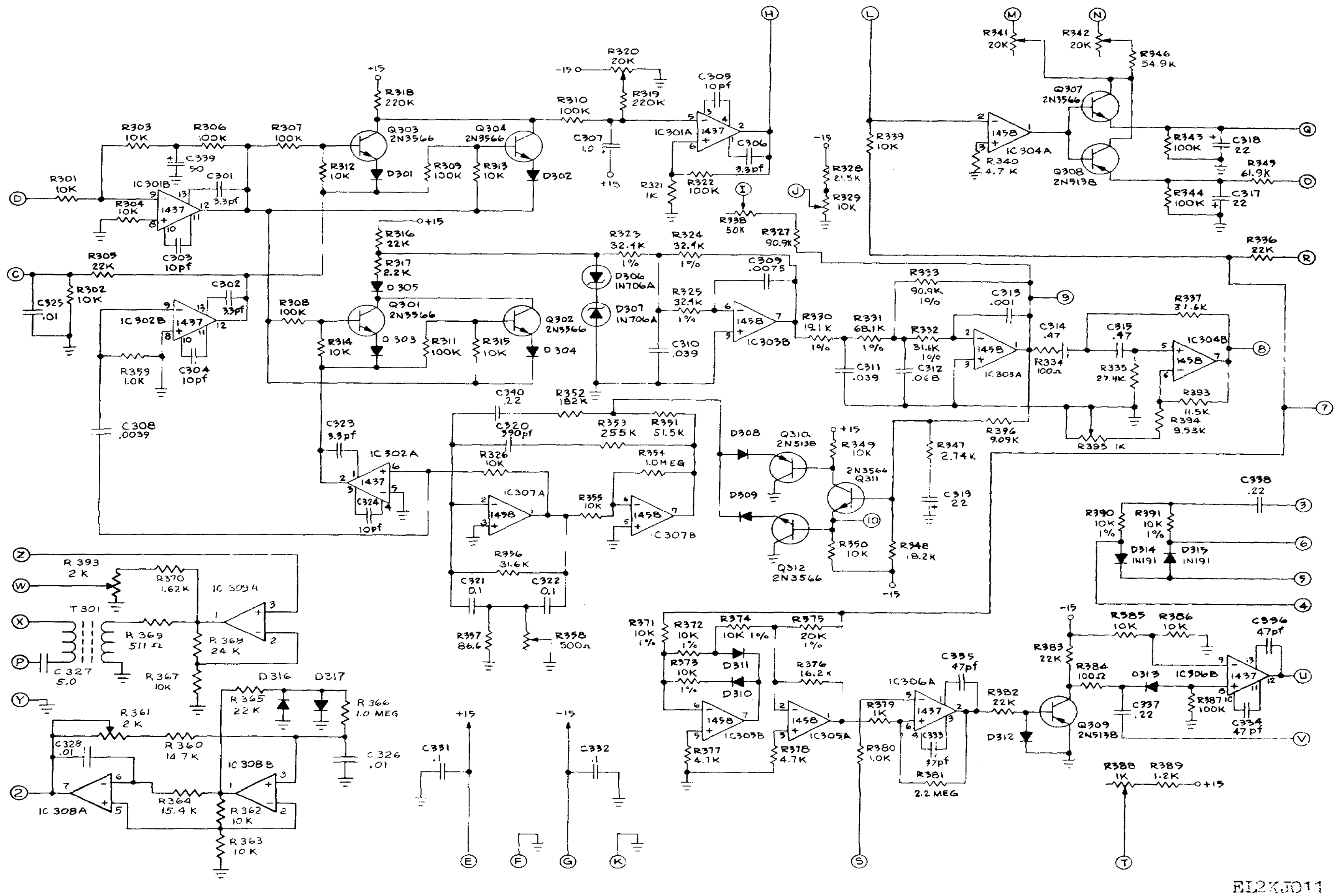


Figure 5-7. HLI 48-300 P.C. BOARD SCHEMATIC DIAGRAM

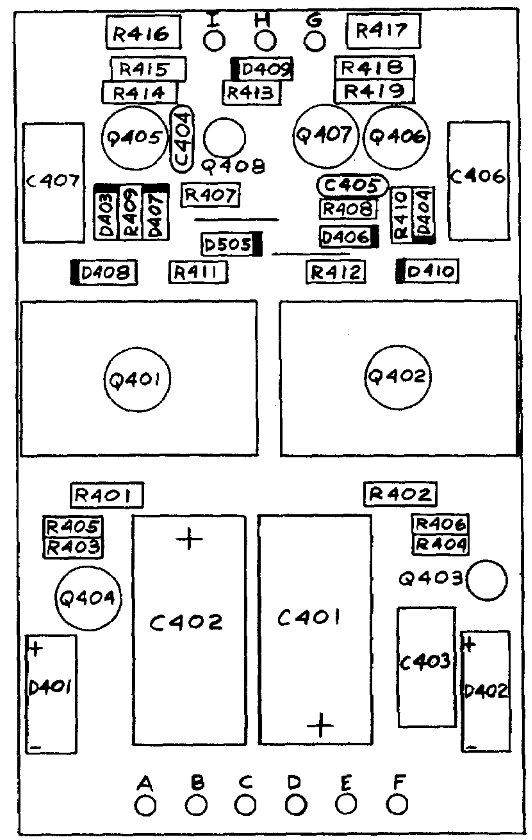


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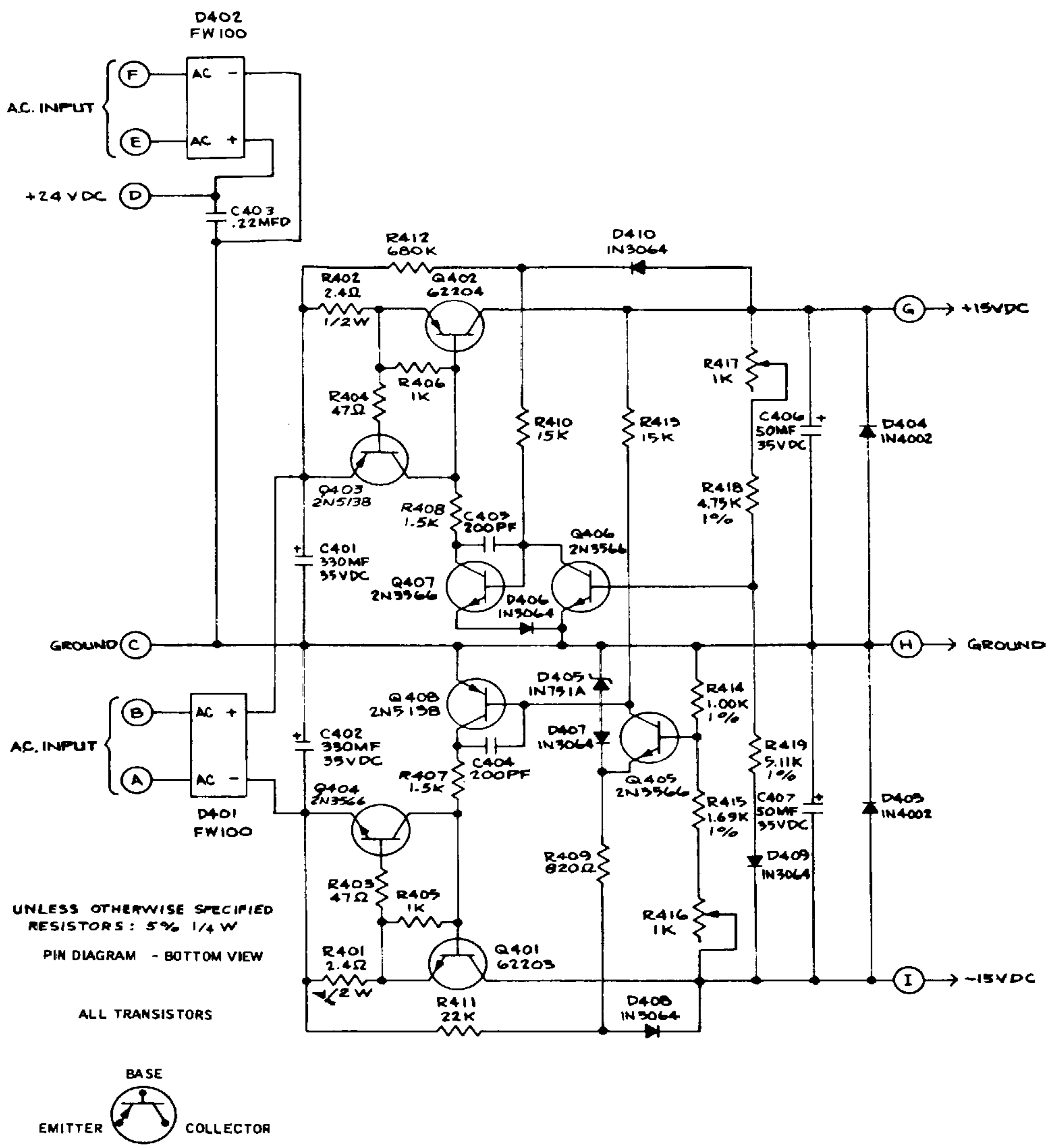
Figure 5-8. HLI PSI-1 P.C. BOARD COMPONENT LAYOUT



E12KJO13

Figure 5-9. HLI PS-1 P.C BOARD SCHEMATIC DIAGRAM

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General, United States Army
Chief of Staff

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