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1.0 DESCRIPTION

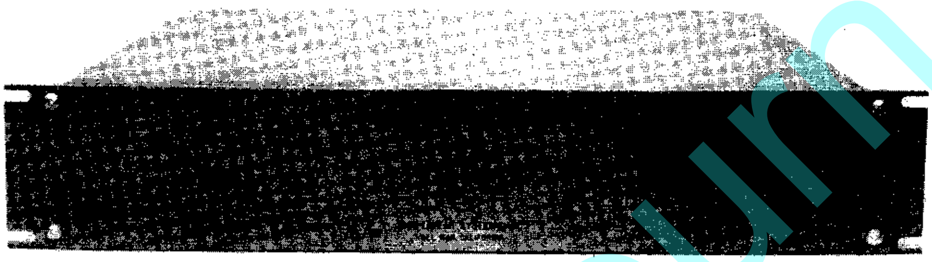
Model 125 Series AC to DC Converters permit making automatic, precise AC voltage measurements when connected to an NLS DC digital voltmeter. Some characteristics of this method of making measurements are:

1. High accuracy over a wide voltage and frequency range, with an input impedance much higher than other types of instrumentation.

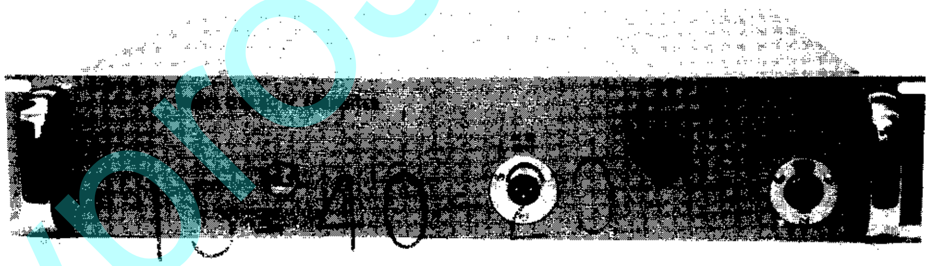
2. Readout directly in numerical form permits easy reading at a single glance even by inexperienced personnel.

3. Readings are clearly visible at distances to 30 feet with no reading error. No leveling is required; and normally encountered vibration has no effect upon accuracy or readability.

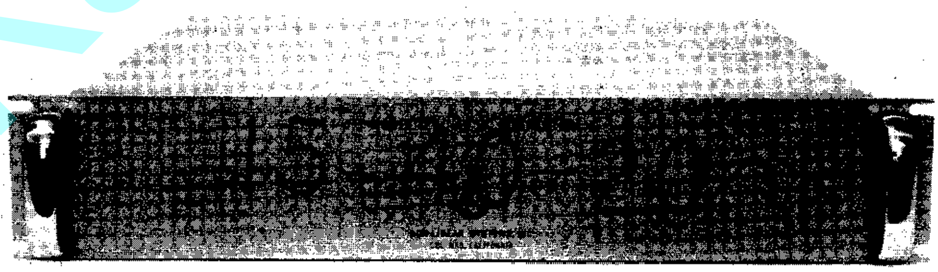
4. Adaptable to automatic systems because readings can be recorded automatically on printers, typewriters or card or tape punches.



Model 125A—Use with Models 451 and 5513A oil bath stepping switch type made after April 1959. Previous Model 451 and 5513 meters require factory modification.



Model 125B—Use with Model 481 Industrial Voltmeter; no modification needed.



Model 125C—Use with Model M24 transistorized mercury relay digital volt-ohm-ratiometer and Models V34 and V35 transistorized stepping switch digital voltmeters; no modification needed.

2.0 SPECIFICATIONS

Input Voltage Ranges:	9.999/99.99/999.9 volts AC, selected by remote contact closures and/or the AC voltage range switch. In Model 125C, the manual AC range switch is on the digital voltmeter front panel; and the readout decimal point is automatically positioned by the range switch. For Models 451 and 5531A, the manual AC range switch is on the Model 125A front panel; and the readout decimal point is automatically positioned by the range switch. For Model 481, the manual AC range switch is on the Model 125B front panel; the readout decimal point position is obtained by reading the range switch position.
Input Impedance:	10 megohms and 20 uuf shunt capacitance.
Output Voltage:	10 volts DC for 10, 100 or 1000 volts AC input (governed by the input voltage range selected) when connected to the 10 megohm input load of an NLS digital voltmeter.
Frequency Range:	30 cps to 10 KC.
Accuracy of AC to DC Conversion (% of full scale on each range):	Scale multiplier accuracy ± 0.1%; voltage linearity ± 0.1%; frequency effect ± 0.1%.
Calibration:	Is in terms of the RMS value of a pure sine wave. The converter output voltage is proportional to the average value of the input voltage.
Balancing Time:	3 seconds, average.
Connections:	Signal input ground and signal output ground are common, but are not connected directly to the AC to DC converter's chassis within the converter. The converter's chassis becomes connected to the digital voltmeter's chassis when converter and digital voltmeter are interconnected. Models 125A and 125C: Input and output connections are each made separately to type MS3102A connectors on the rear panel. Model 125B: Same as 125A and 125C, except input and output connections are also each made separately to Cannon type XL latch-lock connectors at the front panel (since the companion Model 481 input connector is on the 481 front panel.
Dimensions:	3½" high, 15¼" deep, mounts in a standard 19" wide rack.

SECTION 3 — INSTALLATION AND OPERATION

This section is separated into three parts. Part 3A pertains only to the Model 125A, part 3B to Model 125B and part 3C to Model 125C.

SECTION 3A — INSTALLATION AND OPERATION OF MODEL 125A

Refer to Figure 3 for additional information.

1. Connect the MRE 34 connector (J-13) on the converter to the AC converter connector on the rear panel of the DC digital voltmeter, using the cable furnished with the converter.
2. Connect the converter's DC output (connector J-12) to the input terminals of the DC digital voltmeter, using the harness furnished with the converter.
3. Connect the AC or DC input signal to the input connector (J-11) at the rear of the converter:
   Pin "A" — input high side
   Pin "B" — input low side
   Pin "C" — carries shield ground of test leads through converter to DC digital voltmeter.

On AC ranges, the converter's selector switch connects the input signal to the AC-DC conversion circuits. On DC ranges, the selector switch connects the input signal directly to the converter's DC output (connector J-12).
Remember, test lead capacitance can cause appreciable loading of signal circuits, especially at high frequencies.

CAUTION

Chassis ground and signal grounds are not connected together in the converter, but they are connected together in the digital voltmeter. Fuse F-2 (see schematic diagram and Fig. 6-1) protects the wiring against burn out if a "hot" lead is connected to the signal ground terminal. Where completely ground isolated AC signal connections are required, use an external input transformer to isolate the signal circuits from instrument chassis ground. Important factors in transformer selection are: frequency response characteristics, primary impedance, turns ratio accuracy and adequate shielding to prevent noise pick up. Primary impedance is only important because of the effect that a low primary impedance might have upon the output voltage of the circuits being measured. Frequency response characteristics and turns ratio accuracy are important because of the effect they have upon overall measurement accuracy.

4. Set the selector switch, which is located on the digital voltmeter's front panel, to the range of expected use for AC signals or to the "DC" position when measuring DC signals.
5. Turn on the 115 volt AC power.
6. **Decimal Point Location:** In AC measurements, the digital voltmeter readout decimal point location is controlled by the AC range selector switch.
7. **Remote Selection of Range and of AC or DC Measurement:** For remote operation, refer to the block labeled 18045-010 on NLS drawing #18044.
   NOTE: The range selection relays in the converter will operate through switch assembly 18045-010 using the DC relay power supply in the AC to DC converter.

NOTICE

Full accuracy is only obtained with inputs no higher than 10 volts on the 10 volt range, 100 volts on the 100 volt range and 1000 volts on the 1000 volt range.

DO NOT CONNECT MORE THAN 1000 VOLTS TO THE CONVERTER INPUT.

SECTION 3B — INSTALLATION AND OPERATION OF MODEL 125B

Refer to Figure 3 for additional information.

1. Connect J-13 to the 115 volt, 60 cycle power line, using the special line cord furnished with the converter.
2. Connect the converter's DC output (connector J-12) to the input terminal of the DC digital voltmeter, using the harness furnished with the converter.
3. Connect the AC or DC input signal to connector J-11 at the rear of the converter:
   Pin "A" — input high side
   Pin "B" — input low side
   Pin "C" — carries shield ground of test leads through converter to DC digital voltmeter.

On AC ranges, the converter's selector switch connects the input signal to the AC-DC conversion circuits. On DC ranges, the selector switch connects the input signal directly to the converter's DC output (connector J-12).

Remember, test lead capacitance can cause appreciable loading of signal circuits, especially at high frequencies.

Chassis of both the digital voltmeter and the Model 125B are connected to the grounding prong of the 3 prong 115 volt power plug; the chassis grounds of each instrument are thus connected together, as is required for proper operation. If your power receptacles are of the 2 prong type, use a 3 prong-to-2 prong adapter; connect the ground lead of each adapter together; (these ground leads are connected to the ground prong of the 3 prong plugs) and connect the joined leads to a good ground.

CAUTION

Chassis ground and signal grounds are not connected together in the converter, but they are connected together in the digital voltmeter. Fuse F-2 (see schematic diagram and Fig. 6-1) protects the wiring against burn out if a "hot" lead is connected to the signal ground terminal. Where completely ground isolated AC signal connections are required, use an external input transformer to isolate the signal circuits from instrument chassis ground. Important factors in transformer selection are: frequency response characteristics, primary impedance, turns ratio accuracy and adequate shielding to prevent noise pick up. Primary impedance is only important because of the effect that a low primary impedance might have upon the output voltage of the circuits being measured. Frequency response characteristics and turns ratio accuracy are important because of the effect they have upon overall measurement accuracy.

4. Set the AC range selector switch, which is on the converter's front panel, to the range of expected use for AC signals or to the DC position when measuring DC signals.
5. Turn on the 115 volt AC power.
6. Adjust the sensitivity control on the Model 481 digital voltmeter front panel until stable readout is obtained. The control usually must be adjusted because the Model 481 is sensitive to 0.01% changes in input; and more than 0.01% ripple appears in the converter output when measuring low frequency inputs. Also, the stability of most AC voltage sources is generally not as good as 0.01%. It will take longer for the instrument to balance if the sensitivity control is set to maximum (which gives 0.01% sensitivity) rather than to 0.1% sensitivity.
7. Decimal Point Location. Proper decimal point location is obtained by reading the Model 125B selector switch position. The selector switch should be set so readings are made on the digital voltmeter's 0.000 to 9.999 volt range. If the digital voltmeter's range changes to the 99.99 volt range, then you should move the Model 125B selector switch to a higher range.
8. Remote Selection of Range and of AC or DC Measurement: For remote operation, refer to the block labeled 18045-010 on NLS drawing #18044. The range selection relays in the converter will operate through switch assembly 18045-010 using the DC relay power supply in the AC to DC converter.

NOTICE

Full accuracy is only obtained with inputs no higher than 10 volts on the 10 volt range, 100 volts on the 100 volt range and 1000 volts on the 1000 volt range.

DO NOT CONNECT MORE THAN 1000 VOLTS TO THE CONVERTER INPUT.

SECTION 3C — INSTALLATION AND OPERATION OF MODEL 125C

Refer to Figure 3 for additional information.

1. Connect the MRE 34 connector (J-13) on the converter to the AC converter connector on the rear panel of the DC digital voltmeter, using the cable furnished with the converter.
2. Connect the converter's DC output (connector J-12) to the input terminal of the DC digital voltmeter, using the harness furnished with the converter.
3. Connect the AC or DC input signal to connector J-11 at the rear of the converter.
   Pin "A" — input high side
   Pin "B" — input low side
   Pin "C" — carries shield ground of test leads through converter to DC digital voltmeter.

On AC ranges, the converter's selector switch connects the input signal to the AC-DC conversion circuits. On DC ranges, the selector switch connects the input signal directly to the converter's DC output (connector J-12).
Remember, test lead capacitance can cause appreciable loading of signal circuits, especially at high frequencies.

CAUTION

Chassis ground and signal grounds are not connected together in the converter, but they are connected together through the digital voltmeter. Fuse F-2 (see schematic diagram and Fig. 6-1) protects the wiring against burn out if a "hot" lead is connected to the signal ground terminal. Where completely ground isolated AC signal connections are required, use an external input transformer for the signal circuits. Important factors in transformer selection are: frequency response characteristics, primary impedance, turns ratio accuracy and adequate shielding to prevent noise pick up. Primary impedance is only important because of the effect that a low primary impedance might have upon the output voltage of the circuits being measured. Frequency response characeristics and turns ratio accuracy are important because of the effect they have upon overall measurement accuracy.

4. Set the AC range selector switch, which is on the digital voltmeter's front panel, to the range of expected use for AC signals or to the DC position when measuring DC signals.
5. Turn on the 115 volt AC power.
6. It is normal for the digital voltmeter reading to differ each time a measurement is made at low frequencies, even if the AC input voltage is perfectly stable. This happens because NLS four and five digit voltmeters are sensitive to changes of 0.01% and 0.001%, respectively, in input signals, and the AC to DC converter output has more than 0.01% ripple when measuring low frequencies. The difference in consecutive readings will not be so great as to cause the measurement error to exceed the maximum specified error.
7. Decimal Point Location: The digital voltmeter readout decimal point location is controlled by the AC range selector switch. The digital voltmeter's automatic range unit is disabled when the Model 125C converter is connected and when the converter's range selector is on an AC voltage range.
8. Remote Selection of AC Voltage Range and of AC or DC Measurement: For remote operation, refer to the block labeled 18045-010 on NLS drawing #18044. The range selection relays in the converter will operate through switch assembly 18045-010 using the DC relay power supply in the AC to DC converter. Model 125C converter receives its relay excitation voltage from the digital instrument when connected to NLS Model 20 Series instruments.

NOTICE

Full accuracy is only obtained with inputs no higher than 10 volts on the 10 volt range, 100 volts on the 100 volt range and 1000 volts on the 1000 volt range.

DO NOT CONNECT MORE THAN 1000 VOLTS TO THE CONVERTER INPUT.

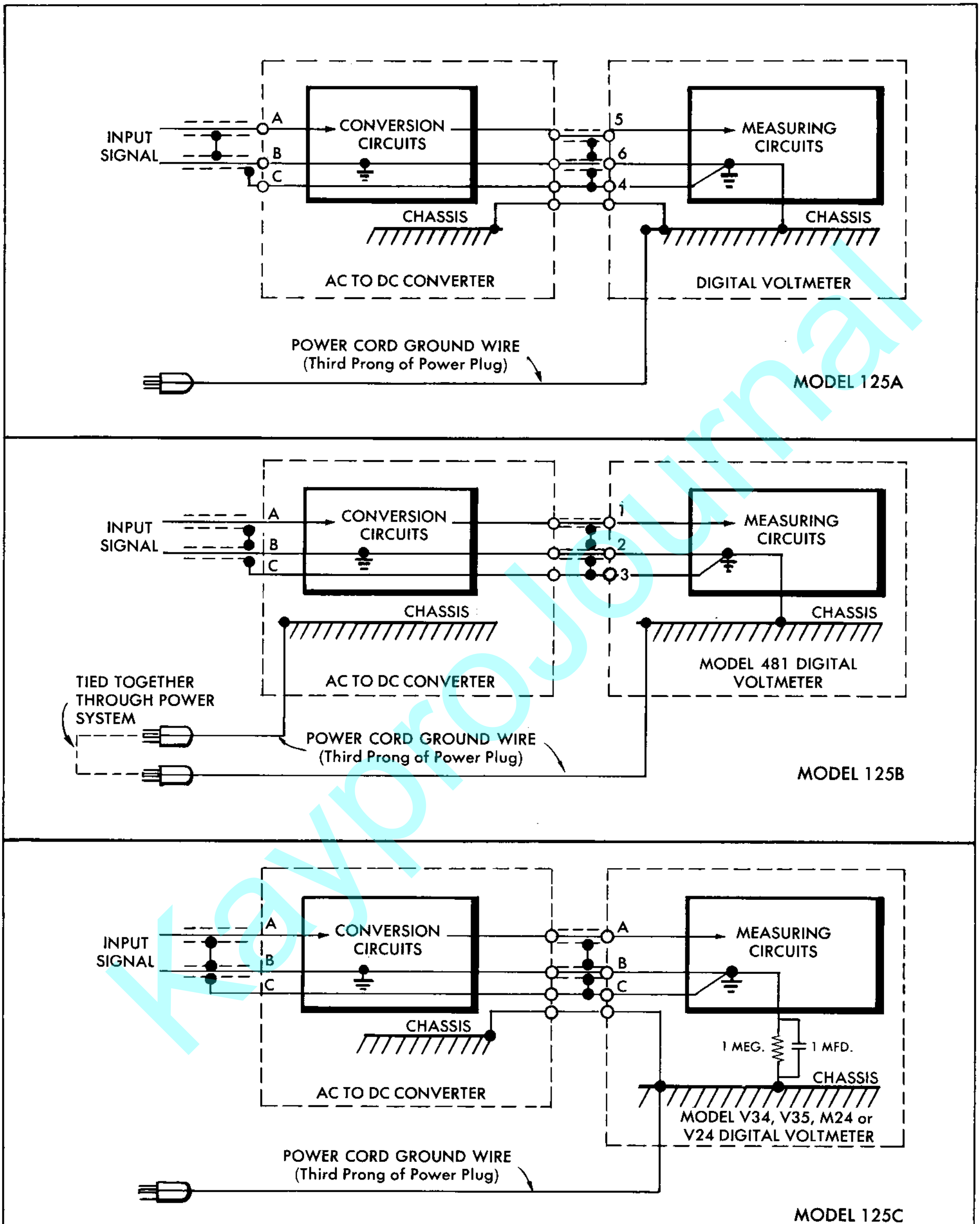


FIG. 3A GROUND CIRCUITS

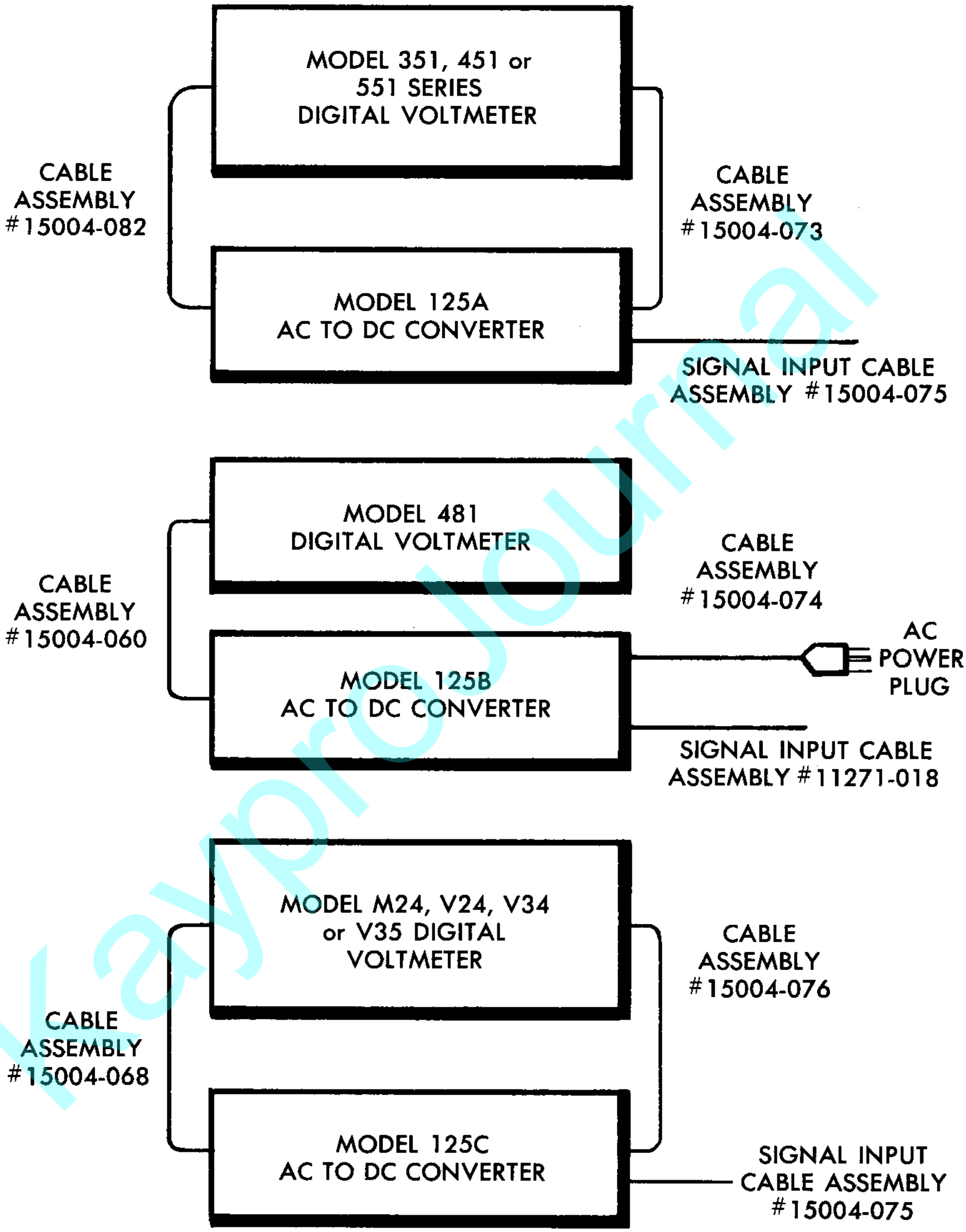


FIG. 3B CABLE ASSEMBLIES, AC TO DC CONVERTER TO DIGITAL VOLTMETER

SECTION 4 — CALIBRATION

4-1 General Procedure:

To calibrate the AC to DC converter, connect the equipment as shown in Figure 4-1; sweep the AC voltage source over the converter's frequency and voltage range, or over the range required in your application; and compare the digital voltmeter readings to readings on the standard AC voltage measuring instrument. If the two sets of readings agree within the possible total error of the AC to DC converter, plus DC digital voltmeter error, plus the standard AC voltage measuring instrument error, plus allowance for drift and harmonic distortion in the AC voltage source during the calibration procedure, then the AC to DC converter is within tolerance. If the AC to DC converter is not within tolerance, follow the procedures of this section to re-adjust it.

4-2 Precautions:

Before calibrating, observe the following precautions:

1. Load the converter's output only with a digital voltmeter of 10 megohm input impedance. The converter has a high output impedance, and small changes in load can affect its DC voltage output appreciably.
2. The calibration signal source must be very stable.
3. The calibration signal source waveform must be sinusoidal with low harmonic content to minimize inaccuracies caused by harmonic distortion. Remember, the AC to DC converter is designed for measuring sinusoidal voltages; its reading is proportional to the average value of the input waveform; and it is calibrated at the factory to indicate the rms value of a pure sine wave. If the signal waveform is not a pure sinusoid, do not expect the AC to DC converter to agree with an AC instrument which measure the waveform rms value (thermal converters, dynamometer type voltmeters, etc.) Differences between AC measurements made with the converter and the true rms values of non-sinusoidal waveforms depends upon relative magnitudes and phase relationships between the fundamental and the harmonics which are present.

The table below shows the maximum differences that can exist between measurements made with the average sensing converter and the true rms value of the waveform being measured. Actual differences may be much less than the maximum differences shown in the table depending upon phase relationships between the fundamental and existing harmonics.

SECOND HARMONIC

% Harmonic	Maximum Error Expected
10%	0.5%
20%	2%
50%	12%

THIRD HARMONIC

.3%	0.1%
.5%	0.17%
1	0.35%
5	1.7%
10%	4.5%
20%	8%
50%	22%

4. Before calibrating the AC to DC converter, the associated DC digital voltmeter must be within its specified accuracy tolerance.
5. Use shielded leads and a good ground, to prevent noise pick-up problems.
6. One input terminal of the AC to DC converter is connected to the digital voltmeter chassis, except in Models M24 and V24 shipped after March 1959 and in Models V35 and V34. Do not apply a potential between the "low" signal input terminal and chassis. A fuse, which is provided to protect instrument wiring, will blow if this is attempted.
7. Do not expect the digital voltmeter reading of those Models 351, 3511, 3512, 3513, 451, 4511, 4512, 4513, 5512 or 5513 which have been modified for AC converter connection to change in steps of one digit in the rightmost window over their entire range when making AC measurements, because an automatic gain control circuit is connected into the DC digital voltmeter to desensitize the error amplifier when the instrument is switched to AC voltage range. However, resolution should be 0.1% of the voltage value read, or better.

8. For the best results, permit the AC to DC converter to warm up for ½ hour before readjusting its calibration controls.
9. Any voltage dividers used in the calibration procedure must be frequency compensated. At high frequencies, test wiring capacitances and AC to DC converter input capacitance can cause appreciable loading; therefore, test leads should be as short as possible.
10. As in most measuring instruments, calibration is more accurate when performed near the top of each voltage range.
11. Instructions below mention frequencies of "30 to 100 cps" and "10 kc." Other frequencies between 30 cps and 10 kc can be be used if the above frequencies are not available. For example, 400 cps can be used for low frequency adjustments and 5 kc for high frequency adjustments; then, the possibility of error below 400 cps and above 5 kc must be accepted. If your application requires use at a single frequency, maximum accuracy will be obtained if you calibrate at that one frequency.
12. The time required for calibration will be much shorter if you plot, on graph paper, the readings obtained after each step below. Then, the effect of each control will be readily apparent. After examining the graph, you can better manipulate the controls to bring the converter into tolerance by, for example, causing an intentional error in one direction at a certain frequency to cause the curve of frequency vs error to come within tolerance at other frequencies. Another reason why the plotted readings are helpful is that the frequency compensation controls have a much greater effect at higher frequencies than at lower frequencies. Figure 4-3 shows a plot of error vs frequency for a typical converter after calibration.

4-3 Adjustment Procedure:

See Fig. 4-2 for location of controls accessible after removing front panel by removing the screws which hold the rack handles. Use a non-metallic screwdriver to turn the calibration control shafts. The phrases "for agreement" or "to achieve agreement" used below mean "bring the digital voltmeter reading within the accuracy tolerance required."

1. Switch the converter to the 10 volt range.
2. With an input voltage slightly less than 10 volts at a frequency between 30 and 100 cps, adjust R-5 ("low freq. adjust 10 v") for agreement.
3. With an input voltage slightly less than 10 volts at a frequency of 10 kc, adjust C-13 (located on main printed circuit board) for agreement.
4. Switch the converter to 100 volt range.
5. With an input slightly less than 100 volts at a frequency between 30 and 100 cps, adjust R-6 (labeled "low freq. adjust 100 v") for agreement.
6. With an input voltage slightly less than 100 volts and at a frequency of 10 kc, adjust C-6 ("high freq. adjust 100 v") for agreement.
7. Repeat Step 5 and re-adjust R-6 ("low freq. adjust 100 v") if needed to achieve agreement. If R-6 required re-adjustment, repeat Step 6 again. It may be necessary to repeat Steps 5 and 6 several times to achieve agreement at low and high frequencies. The adjustment of R-6 and C-6 can be speeded up by realizing that R-6 affects both the low and high frequency calibration, while C-6 affects mostly the high frequency calibration.
8. With an input voltage of at least several hundred volts and at a frequency of between 30 and 100 cps, adjust R-7 ("low freq. adjust 1000 v") for agreement.
9. With an input voltage of several hundred volts at 10 kc, adjust C-7 ("high freq. adjust 1000 v") for agreement.
10. Repeat Step 8 and re-adjust R-7 ("low freq. adjust 100") if needed to achieve agreement. If R-7 requires re-adjustment, repeat Step 9 again. It may be necessary to repeat Steps 8 and 9 several times to achieve agreement at low and high frequencies. The adjustment of R-7 and C-7 can be speeded up by realizing that R-7 affects both the low and high frequency calibration, while C-7 affects mostly the high frequency calibration.
11. C-7 and C-6 will interact slightly if either one required a large change during calibration. Repeat Steps 5 and 6 to check interaction.
12. The AC to DC converter is now properly calibrated. If the range of any of the converter's calibration controls was found insufficient, then R-8 ("low freq. adjust prime") may require re-adjustment; or it is possible that the converter is not operating properly. R-8 has been adjusted at the factory and normally should not require readjustment. R-8 will affect the calibration of all ranges. To adjust R-8, go to the step where it was found that a calibration control did not have enough range and adjust R-8 in the proper direction to permit calibration. Re-check the entire calibration if R-8 requires any re-adjustment.

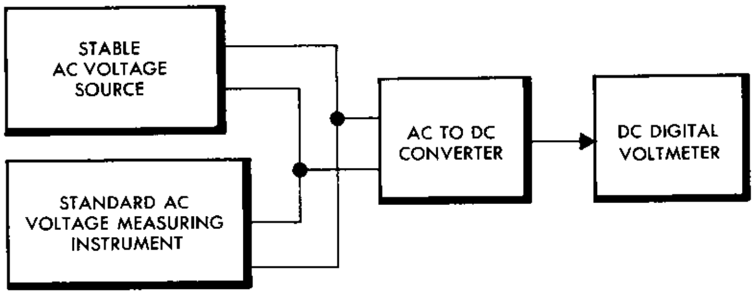


FIG. 4-1 FLOW DIAGRAM OF CALIBRATION SET-UP

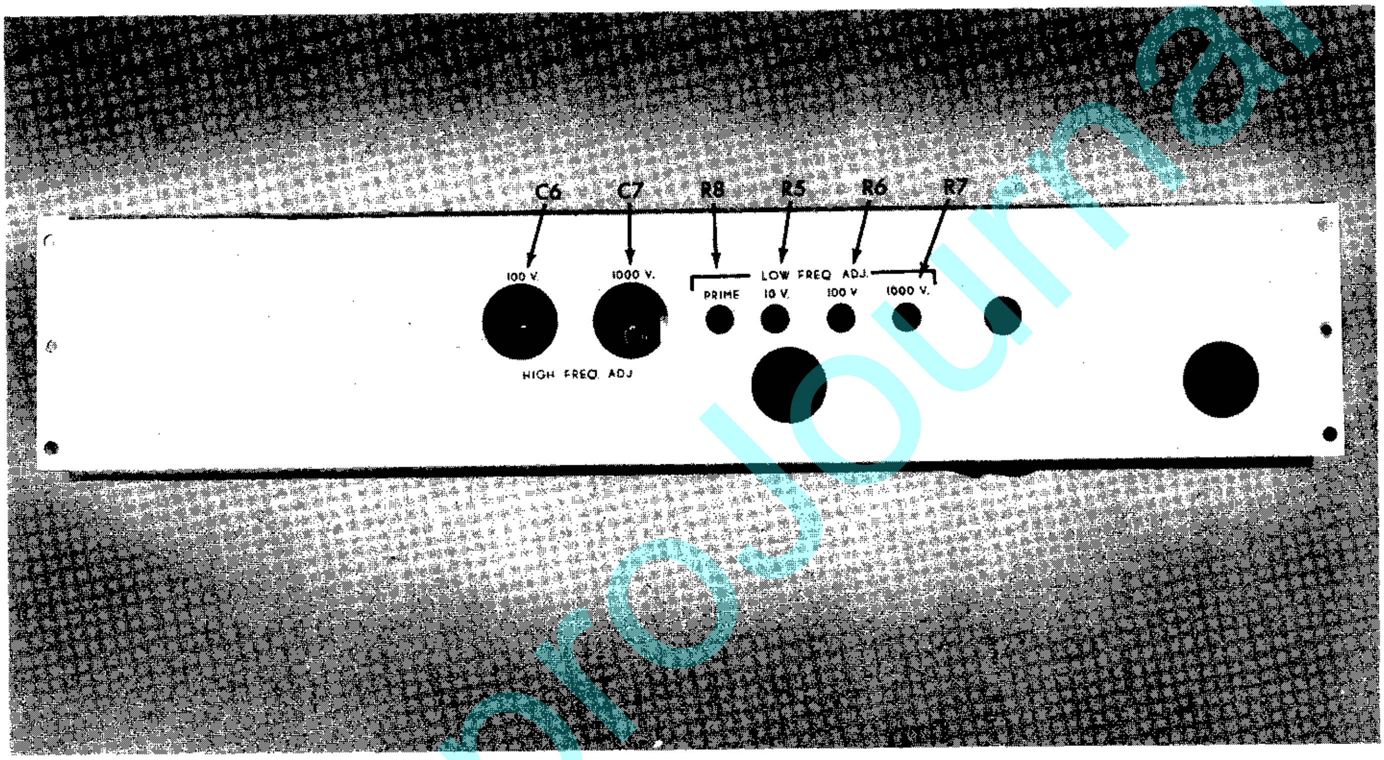


FIG. 4-2 LOCATION OF CALIBRATION CONTROLS, WHICH ARE ACCESSIBLE AFTER FRONT PANEL HAS BEEN REMOVED.
NOTE: C-13 IS INSIDE THE UNIT.

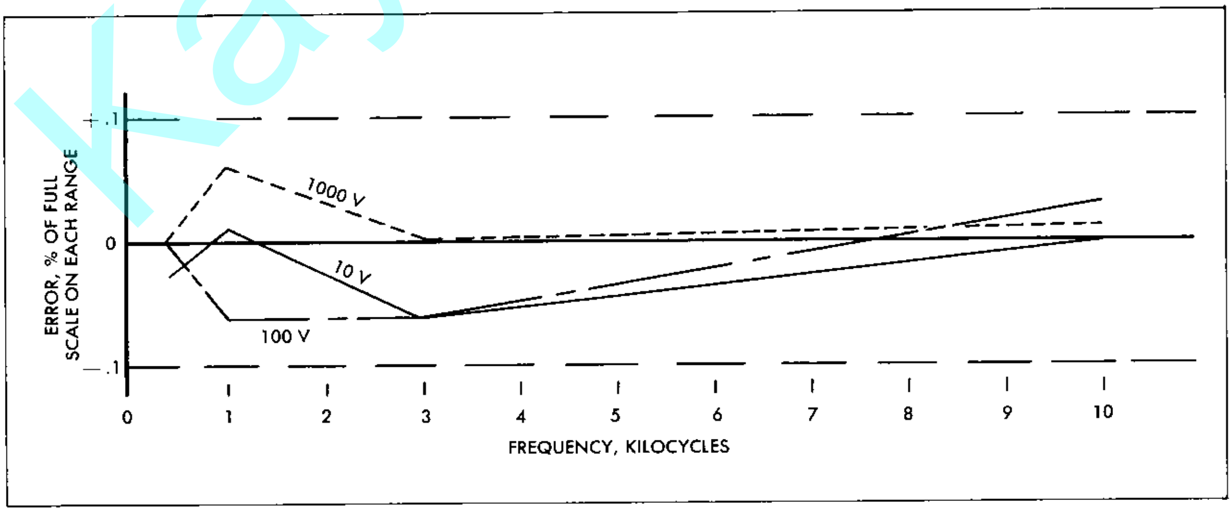


FIG. 4-3 PLOT OF ERROR VS FREQUENCY FOR A TYPICAL AC TO DC CONVERTER AFTER CALIBRATION

SECTION 5 — THEORY OF OPERATION

Introduction

In the Model 125 Series AC to DC converters, semiconductor diodes convert the unknown AC input to pulsating DC, which is then filtered to obtain a very pure DC voltage proportional to the average value of the AC input waveform. A high gain feedback system linearizes and stabilizes the rectification characteristics of the diodes.

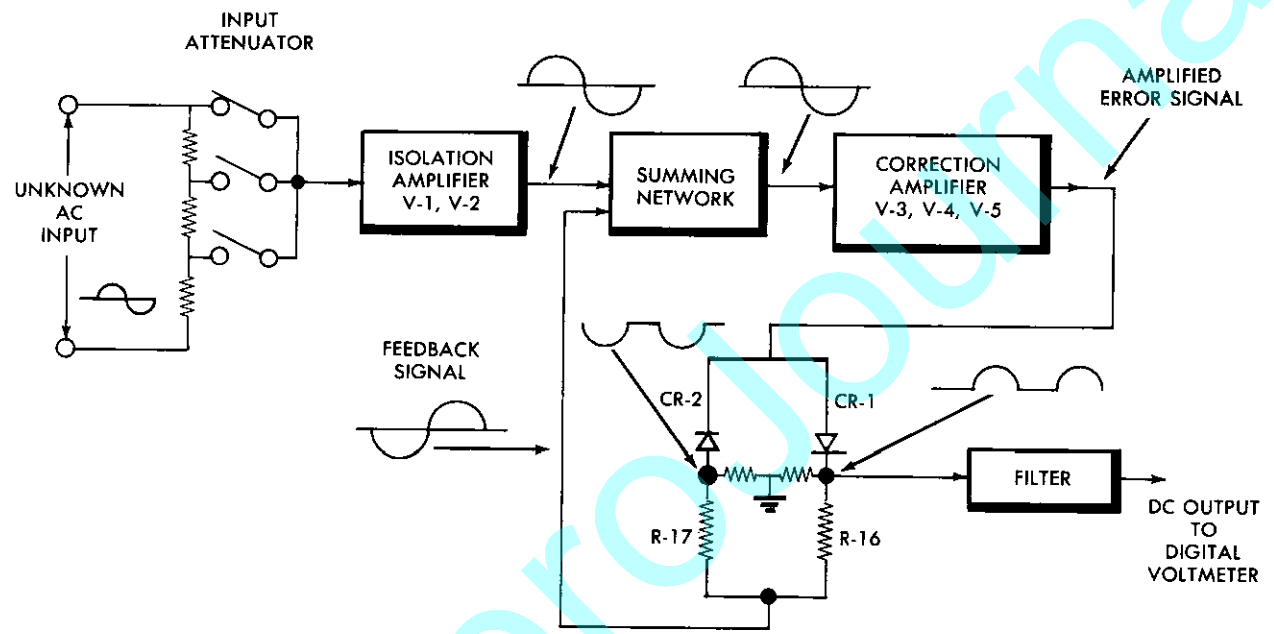


FIG. 5 SIGNAL FLOW DIAGRAM

Block Diagram Description

The converter's input attenuator (range unit) attenuates the unknown AC input by precisely 10:1 or 100:1, as required to restrict the conversion circuit input to 10 volts maximum for full scale inputs of 100 volts and 1000 volts, respectively. C-6 and C-7 provide frequency compensation adjustment in the attenuator on the 100 volt and 1000 volt ranges, respectively.

The attenuator output is fed into a high input impedance isolation amplifier, V-1, V-2A, and V-2B, which prevents the summing network, R-18, R-19, R-20, R-21, C-13 and C-15 from loading the input attenuator.

The summing network sums the isolation amplifier output with a 180° out of phase feedback voltage derived from the converter output stage. C-13 permits adjusting the summing network frequency compensation.

The summing network output is amplified by the high gain amplifier, V-3, V-4 and V-5, and rectified by diodes CR-1 and CR-2. The half-wave output of CR-1 is filtered, and forms the DC output of the AC to DC converter. The feedback signal is obtained by mixing the half-wave outputs of CR-1 and CR-2. R-5, R-6, R-7, R-8 and R-9 form adjustable output voltage dividers which permit changing the scale factor on each range to simplify calibrating the converter. R-8 affects all ranges. Relays K-3 and K-6 operate when selecting the mode of operation (AC measurements or DC measurements), K-1, K-2, K-4 and K-5 operate when selecting AC voltage range. The switch assembly 18045-010 is not installed on Model 125C because an AC voltage range switch is provided in the digital voltmeters which operate with Model 125C. An internal 28 volt DC supply furnishes power for relays in the converter. However, in some cases, the relays are operated from external power sources, which must be well filtered to prevent hum problems.

SECTION 6 — TROUBLESHOOTING

A. GENERAL

Troubleshooting is much easier once one becomes completely familiar with the installation and operation instructions and general theory given elsewhere in this handbook.

The first general step in correcting any trouble which may develop in the AC to DC converter is to isolate the section or sections of the circuit causing the trouble. The trouble-shooting tables and tube socket voltage charts at the end of this section will help localize the trouble. Systematic signal tracing can locate troubles not mentioned in the charts. For additional maintenance help, contact the NLS representative in your area or the Service Manager, Non-Linear Systems, Inc., Del Mar, California.

B. TEST EQUIPMENT

The only test equipment required for maintenance of the AC to DC converter are a VTVM and oscilloscope. Special equipment needed for calibrating the converter are discussed elsewhere in this handbook.

C. SPARE PARTS

Most electronic parts used in the AC to DC converter are standard commercially available items. A complete parts list is included in this handbook. Contact the Service Manager, Non-Linear Systems, Inc., Del Mar, California if you are unable to obtain electronic parts, or if mechanical parts are required.

D. SIGNAL TRACING

This section gives information to aid in tracing signals through the AC to DC converter. Refer to Figure 5, Signal Flow Diagram and the converter's schematic for additional information. Most voltage measurements are made with respect to signal ground. A signal ground terminal is located near the forward end of the metal shield plate near V-2 (see Fig. 6-1).

1. Set Up: Connect a stable AC voltage to the converter's input terminals. Follow the instructions given in Section 3, Installation and Operation. The AC voltage should be slightly less than 10 volts, unless trouble is evidenced on higher ranges, to avoid saturation.
2. Input Attenuator: The input attenuator output can be measured at pin 1 of V-1. When operating the converter on any range except its lowest, even the load of a VTVM will affect the input attenuator output voltage because of the attenuator's high impedance. At high frequencies, the test lead capacitance can greatly affect the input attenuator output voltage. Loading effects present so great a problem that measuring the attenuator's output voltage is generally of little help in trouble-shooting.

CAUTION: Do not bend the wires which interconnect the range attenuator components. Attenuator wiring capacitances are very critical; and the calibration will be affeced by capacitance changes.

3. Isolation Amplifier: The output of the converter's isolation amplifier is measured at pin 7 of V-1. The isolation amplifier is an accurate unity gain amplifier; therefore, its output voltage should be equal to its input voltage. If it will help isolate trouble, disconnect he unity gain amplifier and drive the remainder of the AC to DC converter from an AC signal source. To perform this disconnection, unsolder the lead which connects C-15 to the following: R-21, C-19, C-18 pin 2 and 7 of V-1. Connect the AC input signal to the unsoldered end of C-15.
4. Correction Amplifier: The correction amplifier is best tested by measuring the error signal at pin 1 of V-3. The error signal is normally 40 millivolts, maximum. A large error signal usually indicates absence of feedback voltage. Feedback voltage is developed by the correction amplifier output at pin 7 of V-5 then through C-25, CR-1 and CR-2 and R-16 and R-17. The summing network, which consists of R-18, R-19 and C-13, sums the isolation amplifier output and diode CR-1 and CR-2 output to form an input (error signal) for the correction amplifier.
5. Conversion Diodes: When a 10 volt RMS sine wave is applied to the converter's input terminals, the voltage from the junction of CR-1 and R-16 to ground and the voltage from the junction of CR-2 and R-17 to ground should be approximately 22 volts peak. The waveform at each of these junctions should be a half-wave rectified sine wave. Use a low capacitance probe when measuring CR-1 and CR-2 output.
6. Output Filter: The output filter (R-10, R-11, R-12, C-9, C-10 and C-11) filters the half-wave output of CR-1 to form the pure DC output signal. The filter's time constant is relatively long since it must reduce the ripple in the converter output to less than 0.1%, even with AC inputs as low as 30 cps; and CR-1 output contains a large AC component. Because of the high series resistance of the output filter, the converter's output voltage will be greatly affected by the load connected to the converter output terminals. The converter's output voltage is correct only when its load is an NLS digital voltmeter with 10 megohms input impedance.

TUBE SOCKET VOLTAGES

These voltages are useful as a troubleshooting guide. They were measured with respect to signal ground (see Fig. 6-2), not to chassis ground. Generally, considerable voltage variation can be tolerated. The line voltage was 115 volts. "Fil" means Filament.

Measured With 10 Megohm Input VTVM (HP 410 B)

	SOCKET PIN								
TUBE	1	2	3	4	5	6	7	8	9
V1	20	22.7	Fil	Fil	86	78	22.7	—	—
V2	210	25.5	27.5	Fil	Fil	278	18	21.5	Fil
V3	0	1.38	Fil	Fil	278	59	1.38	—	—
V4	0	1.38	Fil	Fil	137	59	1.38	—	—
V5	2.6	1	2.6	Fil	Fil	Fil	155	135	2.6
V6	255	278	Fil	Fil	520	520	255	—	—
V7	255	278	Fil	Fil	520	520	255	—	—
V8	258	170	170	Fil	Fil	170	84	85	Fil
V9	85	0	—	0	85	—	0	—	—

Measured With 20,000 Ohms/Volt Voltmeter

	SOCKET PIN								
TUBE	1	2	3	4	5	6	7	8	9
V1	—	22	Fil	Fil	80	75	22	—	—
V2	205	—	27	Fil	Fil	275	—	21	Fil
V3	—	1.35	Fil	Fil	275	54	1.35	—	—
V4	—	1.35	Fil	Fil	135	54	1.35	—	—
V5	2.5	—	2.5	Fil	Fil	Fil	150	130	2.5
V6	250	275	Fil	Fil	520	520	250	—	—
V7	250	275	Fil	Fil	520	520	250	—	—
V8	258	170	170	Fil	Fil	170	83	84	Fil
V9	84	0	—	0	84	—	—	—	0

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Converter output voltage high (about 24 volts) for any value of input signal.	Feedback voltage is not reaching correction amplifier.	Correct the open circuit or faulty component between conversion diodes and correction amplifier input.
Converter output voltage very low on 100 or 1000 volt ranges.	Range selector switch is on wrong range.	Select proper range.
	Open circuit or faulty resistor in input attenuator.	Replace faulty component.
	Faulty range relay K-1, K-2, K4 or K5.	Replace faulty relay.
Converter output exceeds several millivolts with input leads grounded.	Excessive hum pick-up from heater to cathode leakage in some vacuum tube.	Replace faulty vacuum tube.
Converter output zero, or very low and continuously drifting.	Ground fuse, F-2, blown.	Replace fuse. Do not connect "hot" lead to signal "low" side terminal.
	Relays K-3 or K-6 faulty.	Replace faulty relay.
	Faulty vacuum tube.	Replace tubes.
Converter output voltage zero on any one range.	Range calibration pots R-5, R-6 or R-7 open circuited.	Replace faulty components.
	Range relays K-4 or K-5 faulty.	
Converter output much too high on all ranges at all frequencies.	R-8 (prime calibration pot) or R-9 open circuited.	Replace faulty components.
Converter output continously drifts.	Low B+ voltage.	Repair power supply or remove excessive load from power supply.
Tube filaments do not light and blower does not operate.	Power fuse, F-1, blown.	Replace fuse. Examine circuits for excessive loads.
When measuring low frequency signals, converter can be almost, but not completely, brought into tolerance.	Prime calibration, R-8, requires adjustment.	Readjust R-8. See calibration procedure.
When measuring high frequency signals, converter can be almost, but not completely, brought into tolerance.	10 volt high frequency compensator, C-13, requires readjustment.	Readjust C-13. See calibration procedure. Use non-metallic screwdriver.
	Low frequency calibration controls must be readjusted sufficiently to permit bringing calibration in at high frequencies.	Recalibrate entire converter. See calibration procedure.
Converter output very non-linear as a function of input frequency.	Conversion diodes CR-1 or CR-2 are bad.	Replace faulty diodes.
With input above 10 volts to Model 125B, the digital voltmeter reads higher than 9.999 volts, although range switch is on proper range.	Faulty range relays.	Replace faulty component or repair wiring.
	Faulty range switch on converter (125B) or digital voltmeter (125A or 125C).	
	Relay excitation supply failure.	
With input above 10 volts to Model 125A or 125C, digital meter reads low by 10 or 100 times or reads no higher than about 24.00 or 240.0 volts.	Faulty cable or connector between Model 125C or 125A and digital voltmeter.	
Converter cannot be brought into tolerance on 100 or 1000 volt ranges when measuring low and high frequency signals.	V-1 drawing excessive grid current.	Replace V-1.
Digital voltmeter connected to converter will not measure DC voltages.	K-6 faulty.	Replace K-6.
Entire AC input signal appears at converter output.	K-6 faulty.	Replace K-6.

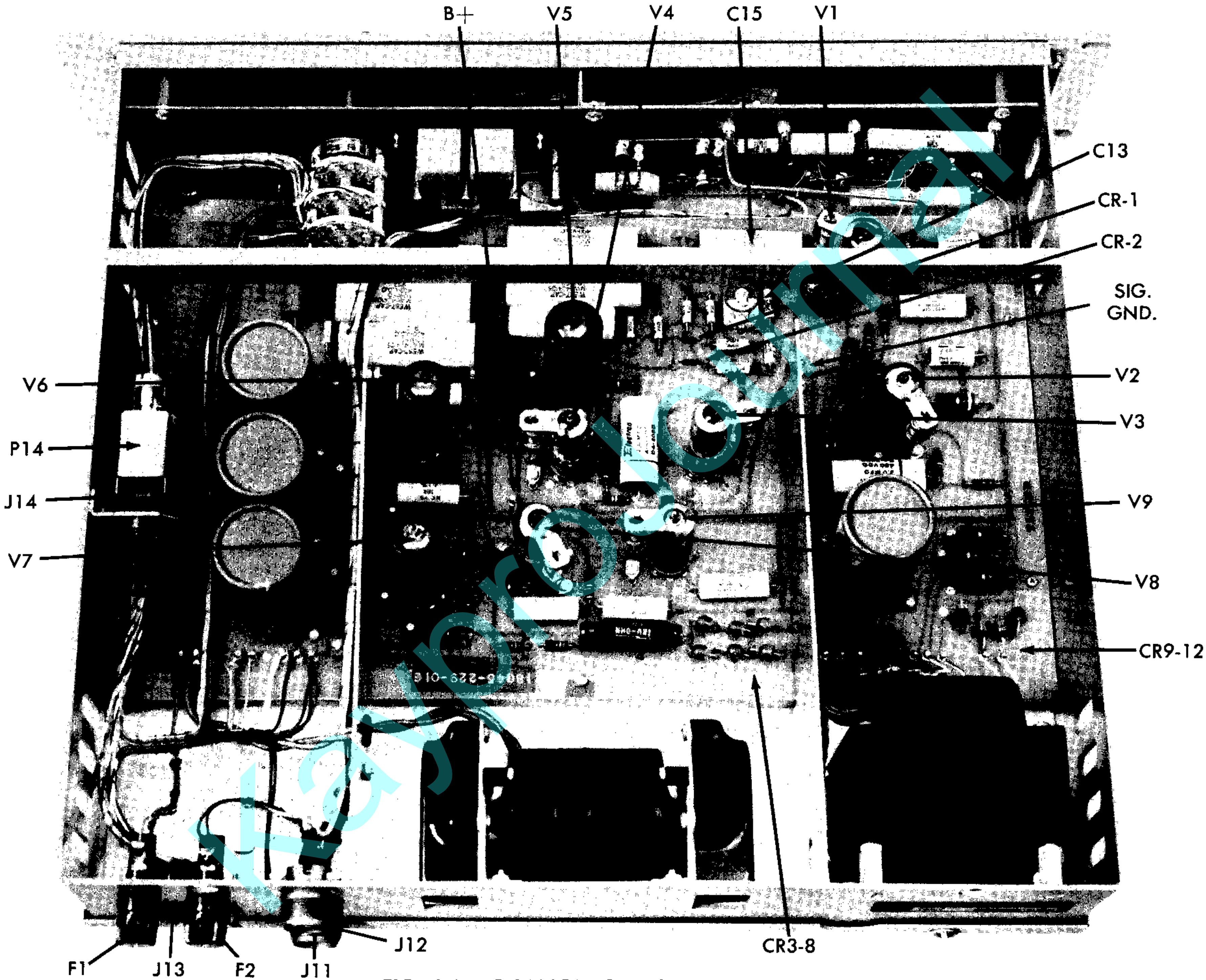


FIG. 6-1 LOCATION OF COMPONENTS

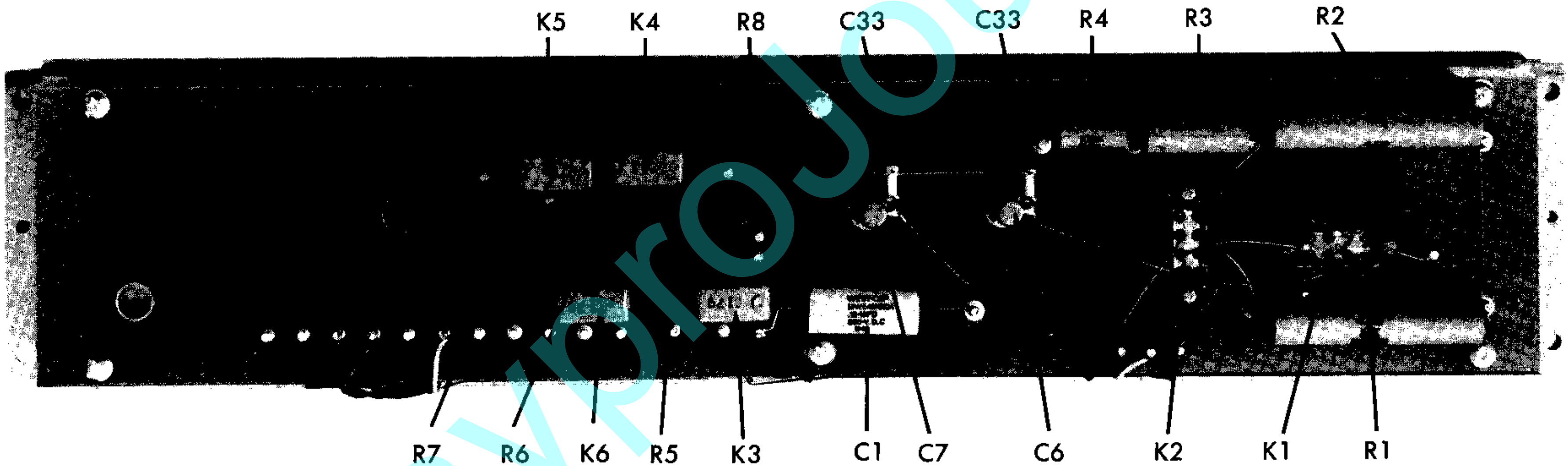


FIG. 6-2 LOCATION OF RANGE ATTENUATOR COMPONENTS

SECTION 7 — PARTS LIST

PARTS USED ONLY IN MODEL 125A

CIRCUIT REFERENCE	DESCRIPTION	PART NO.	MFR. CODE
	Switch, 6 Pole, 2 - 6 Pos., Shorting	PA-2022	G
	Switch, 6 Pole, 2 - 6 Pos., Non Shorting	PA-2023	G
P - 14	34 Pin Connector & Hood	MRE-34P-JTCH-6	CC
	Knob with Skirt, Matte Finish, Black	70-3-2G	X
P - 13A (on ext. cable)	34 Pin Connector & Hood	MRE-34S-JTCH-6	CC
On ext. cable	50 Pin Connector & Hood	MRE-50P-JTCH-6	CC
	Cable, 9 Pair (18 conductors)	8748	E
P - 12A	Connector, Blue Diallyl Phthalate, Gold Pins	MS-3106A-14S-7P	C
	Clamp & Rubber Insert 18220-6	AN-3057-6A	C
P - 11A	Connector, Blue Diallyl Phthalate, Gold Pins	MS-3106A-14S-7S	C

PARTS USED ONLY IN MODEL 125B

CIRCUIT REFERENCE	DESCRIPTION	PART NO.	MFR. CODE
	Switch, 6 Pole, 2 - 6 Pos., Shorting	PA-2022	G
	Switch, 6 Pole, 2 - 6 Pos., Non Shorting	PA-2023	G
P - 14	34 Pin Connector & Hood	MRE-34P-JTCH-6	CC
	Knob with Skirt, Matte Finish, Black	70-3-2G	X
J - 11B	Connector	XLR-3-14	F
J - 12B	Connector (Reworked by NLS)	XLR-3-13	F
	Coaxial Cable, Subminiature	21-598	C
	Connector	XLR-3-11C	
P - 13B (on pwr. cable)	Connector & Hood	MRE-34S-JTCH-6	CC

PARTS USED ONLY IN MODEL 125C

CIRCUIT REFERENCE	DESCRIPTION	PART NO.	MFR. CODE
	Cable, 9 Pair (18 conductors)	8748	E
On ext. cable	Connector & Hood	MRE-34P-JTCH-6	CC
P - 13C (on ext. cable)	Connector & Hood	MRE-34S-JTCH-6	CC
	Connector, Blue Diallyl Phthalate, Gold Pins	MS3106A-14S-7S	C
P - 12C	Connector, Blue Diallyl Phthalate, Gold Pins	MS3106A-14S-7P	C
	Clamp & Rubber Insert 18220-6	AN 3057-6A	C

PARTS USED IN MODELS 125A, 125B AND 125C

CIRCUIT REFERENCE	DESCRIPTION	PART NO.	MFR. CODE
C8, C25	Capacitor, 0.47 mf, 400V, ±5%, Ext. Foil, Mylar	MW64M4474	BB
C9, C10, C11, C12	Capacitor, 1 mf, 150V DC, Ext. Foil, Mylar	MWG64J4105	BB
C15	Capacitor, 1.5 mf, 400V, ±10%	MW64K1J155	BB
C18, C27, C28	Capacitor, 0.1 mf, 400V, ±20%	MW64M4104	BB
C13	Capacitor, 4-25, NPO CV11A250, Ceramic Trimmer	822 AZ	G
C14	Capacitor, 20mf, 25WVDC, Ceramic Cased	PWE-25020	A
C16	Capacitor, 50mmf, 500 VDC, Silver Mica	CM-15E-500J	D
C19	Capacitor, 100mf, 3WVDC, Ceramic Cased	PWE-3100	A
C20	Capacitor, 200 mmf, 500 VDC, Silver Mica	CM-15E-201J	D
C17	Capacitor, .002 mf, 600 VDC, Molded Paper	6D2 CUB	K
C21, C22	Capacitor, 2 mf, 400 V, ±5%, Metallized Mylar	D4205D	M
C23	Capacitor, .01 mf, 600 WVDC, Disc Ceramic	DD6103	G
C26, C29	Capacitor, 50 mf x 50 mf, 350 VDC, Royalitic	30B257RTK	R
C24	Capacitor, 115 mf, 350 VDC, Royalitic	30B256RTK	R
C30	Capacitor, 50 mf, 350 VDC, Royalitic	30B261RTK	R
C31, C32, C33	Capacitor, 250/250/250, 50 WVDC, Royalitic	1B1011RTK	R
	Wafer	BP-6	V
CR1, CR2	Diode, Silicon, 150 V PIV	1N458 (HD6007)	P
CR3, CR4, CR5, CR6, CR7, CR8, CR9, CR10, CR11, CR12	Diode, Silicon, 600 V PIV	F-6 (1N2071)	AA
V1, V3, V4	Vacuum Tube, Pentode, 7 Pin, no substitution	6136	Y

PARTS USED IN MODELS 125A, 125B AND 125C

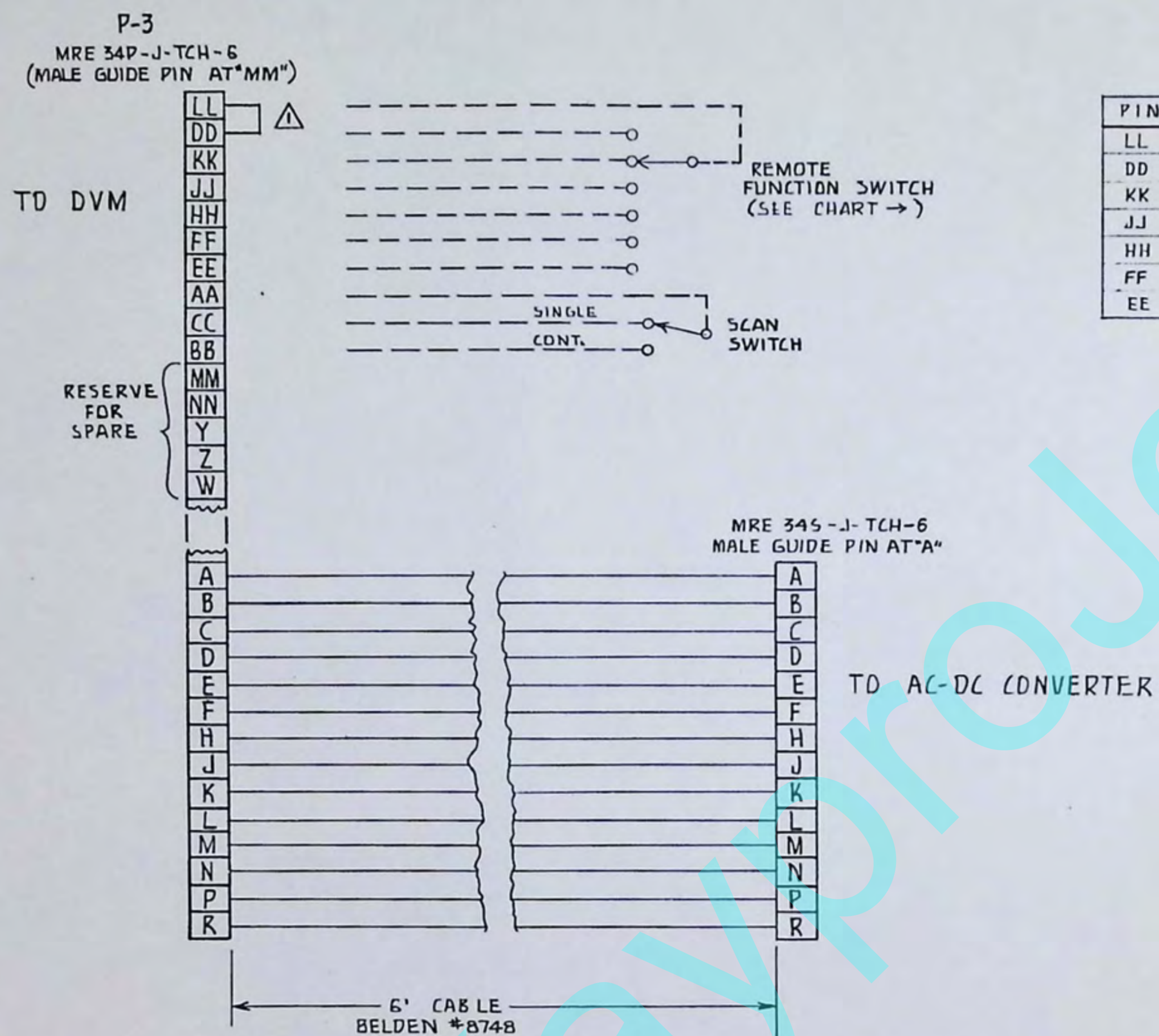
CIRCUIT REFERENCE	DESCRIPTION	PART NO.	MFR. CODE
J - 11	Connector, 3 Pin, Plug, Blue Diallyl Phthalate, Gold Pins	MS3102A-14S-7P	C
J - 12	Connector, 3 Pin, Socket, Blue Diallyl Phthalate, Gold Pins	MS3102A-14S-7S	C
J - 14	Connector, 34 Pin, Socket	MRE-34S-J6	CC
	Dual 1-1/2 Blower and Motor, 60 cy, 115 V AC	8437	Z
J - 13	Connector, 34 Pin, Plug	MRE-34P-J6	CC
	Fuse Holder	342003	U
	Fuse, I Ampere, 3AG-1A	313001	U
K3, K4, K5, K6	Relay, DPDT, Type F, 675 OHM, 28 VDC, 3" Lead, Lead Mtg.	RP7641G2	I
R5, R6, R7, R8	125 K Potentiometer, Miniature	0250L-1-125K	J
K1, K2	Relay, DPDT, Type F, 675 OHM, 28 VDC, 3" Lead, Flange Mtg.	RP9003G1	I
C2, C3	Capacitor, 20 uuf, 500 VDC, Silver Mica	CM-15C200J	D
C4	Capacitor, 200 uuf, 500 VDC, Silver Mica	CM-15E201J	D
C5	Capacitor, 1800 uuf, 500 VDC, Silver Mica	CM-20E182J	D
C1	Capacitor, .1 mf, 600 VDC, ±20%, Mylar Wrap	MW64M6104	BB
C6, C7	Capacitor, .5-3 uuf Rotary Trimmer, Invar Core	683038	L
C34, C35	Capacitor, 6.8 mmf (.5 mmf Tol.), NPO, Ceramic Tubular	MPOA-6R8	O
R1, R2	Resistor, 4.5 meg, 2 Watt, 1%, Metallized Film	MEHT-5	S
R3	Resistor, 900 K, 1 Watt, 1%, Metallized Film	MEFT-5	S
R4	Resistor, 100 K, 1/2 Watt, 1%, Metallized Film	MECT-5	S
V2	Vacuum Tube, Dual Triode, 9 Pin, No substitution	6201	Y
V5	Vacuum Tube, Pentode, 9 Pin, No substitution	12BY7	Y
V6, V7	Vacuum Tube, Pentode, 7 Pin	6AQ5	
V8	Vacuum Tube, Dual Triode, 9 Pin	12AX7	
V9	Vacuum Tube, Gas Regulator	5651	
	Tube Socket, 7 Pin, Type 1, For 1/16 Epoxy	53F24022	H
	Tube Socket, 9 Pin, Type 1, For 1/16 Epoxy	44P24023	H
	Tube Socket, 9 Pin/Shield Saddle, For 1/16 Epoxy	44P244429	H
	Tube Socket, 7 Pin/Shield Saddle, For 1/16 Epoxy	87253	H
	Heat Radiator	TR6-6020H	Q
	Heat Radiator	TR5-5020H	Q
R9	Resistor, AXIAL LEAD, 2.2 M, ½ W, 1/20%, Precision, WW	NLS	
R10, R11	Resistor, 100K, ¼W, 1%, Carbon Film	KC60	T
R12, R14	Resistor, 120K, ¼ W, 1%, Carbon Film	KC60	T
R13, R15	Resistor, 10 K, ¼ W, 1%, Carbon Film	KC60	T
R16, R17	Resistor, 500 K, ¼ W, 1%, Metal Film	MEBT-5	S
R18, R19	Resistor, 100 K, ¼ W, 1%, Metal Film	MEBT-5	S
R20, R33	Resistor, 220 K, ½ W, 10%, Composition	EB2241	B
R21	Resistor, 2 K, ½ W, 5%, Composition	EB2025	B
R22, R41	Resistor, 470 K, ½ W, 5%, Composition	EB4745	B
R23	Resistor, 1.2 M, ½ W, 5%, Composition	EB1255	B
R24	Resistor, 3.9 K, 2 W, 5%, Composition	HB3925	B
R25, R29	Resistor, 22 meg, ½ W, 10%, Composition	EB2261	B
R26	Resistor, 10 K, ½ W, 10%, Composition	EB1031	B
R27, R47	Resistor, 2.2 meg, ½ W, 10%, Composition	EB2251	B
R28	Resistor, 3.9 K, ½ W, 10%, Composition	EB3921	B
R30	Resistor, 1.6 meg, ½ W, 5%, Composition	EB1655	B
R31	Resistor, 620 K, ½ W, 5%, Composition	EB6245	B
R32	Resistor, 1.2 K, ½ W, 10%, Composition	EB1221	B
R34, R46	Resistor, 1 K, ½ W, 10%, Composition	EB1021	B
R35	Resistor, 2 meg, ½ W, 5%, Composition	EB2055	B
R36	Resistor, 6 K, 10 W, 5%, Wire Wound	6K Brown Devil	W
R37, R44, R45	Resistor, 100 ohms, ½ W, 10%, Composition	EB1011	B
R38	Resistor, 27 K, 2 W, 5%, Composition	HB2735	B
R39	Resistor, 56 K, 1 W, 1%, Carbon Film	KC75	T
R40, R42	Resistor, 43 K, 1 W, 1%, Carbon Film	KC75	T
R43	Resistor, 100K, 1 W, 10%, Composition	GB1041	B
R48, R49	Resistor, 270 K, ½ W, 10%, Composition	EB2741	B
R50	Resistor, 500 ohms, 10 W, 5%, Wire wound	500 ohms, 10 W	W
R51, R52, R53	Resistor, 100 ohm, 2 W, 10%, Composition	HB1011	B
	Coaxial Cable, 19/.007 Stranded, 1900 VRMS, Max Cap/ft 29.5 mmfd.	RG58A/U(21-199)	C

MANUFACTURER'S CODE

A	Aerovox	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee, Wis.
C	Amphenol	Chicago, Ill.
D	Arco Electronics	New York, N.Y.
E	Belden Mfg.	Chicago, Ill.
F	Cannon Electric Co.	Los Angeles, Calif.
G	Centralab Div. Globe-Union, Inc.	Milwaukee, Wis.
H	Cinch-Jones Mfg.	Chicago, Ill.
I	C. P. Clare Co.	Chicago, Ill.
J	Con Elco Edcliff Instruments	Monrovia, Calif.
K	Cornell-Dubilier Corp.	So. Plainfield, N.J.
L	Corning Glass Works	Corning, N.Y.
M	Electron Products	Pasadena, Calif.
O	Erie Resistor Corp.	Erie, Pa.
P	Hughes Products Co.	Los Angeles, Calif.
Q	I.E.R.C.	New York, N.Y.
R	Industrial Condenser	Chicago, Ill.
S	IRC	Philadelphia, Pa.
T	Key Resistor Corp.	Gardena, Calif.
U	Littlefuse, Inc.	DesPlaines, Ill.
V	Mallory Co., Inc.	Indianapolis, Ind.
W	Ohmite Mfg. Co.	Skokie, Ill.
X	Raytheon Mfg. Co. Commercial Equip Div.	Waltham, Mass.
Y	Any tube brand meeting RETMA specifications	
Z	Ripley	Middletown, Conn.
AA	Sarkes Tarzian Rectifier Div.	Bloomington, Ind.
BB	West-Cap San Fernando Electric Mfg. Co.	San Fernando, Calif.
CC	Winchester Electronics, Inc.	Norwalk, Conn.

REVISIONS

SYM.	EFFECT.	DESCRIPTION	DATE	APPROVAL
1		"BELDEN" CABLE WAS "MOHAWK" (ERROR)	27 MAR 59	1 Mar 31-59 H. Clement



PIN	V24	M24
LL	COMMON	COMMON
DD	VDC	K-OHMS
KK	—	RATIO
JJ	—	VDC
HH	VAC 100-1000	VAC 100-1000
FF	VAC 10-100	VAC 10-100
EE	VAC 0-10	VAC 0-10

15004-076
SHEET 2
1

NOTES: UNLESS OTHERWISE SPECIFIED—

⚠ IF REMOTE FUNCTION SELECTION REQUIRED, REMOVE JUMPERS "LL" TO "DD". THIS APPLIES TO SERIES 20 INSTRUMENTS ONLY.

2. MARK OR STAMP PART NO. & "B UNIT TO AC-DC CONVERTER" ON ALUM. TAG #9-1639 NATIONAL TAG CO. OR EQUIV & ATTACH TO CABLE

NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QTY REQD	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTION ± DECIMAL ± ANGLES ±
MATERIAL
FINISH

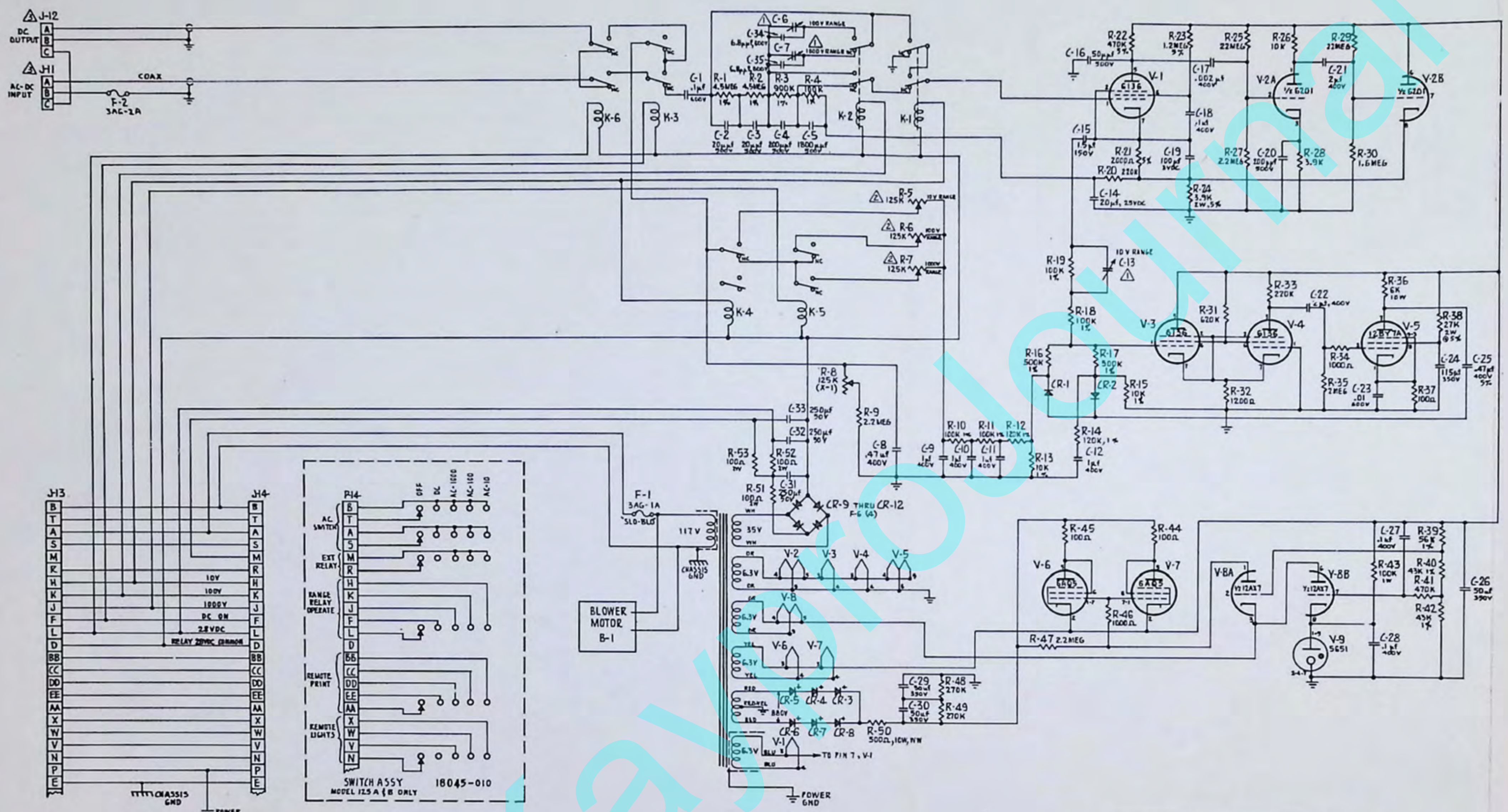
DRAWN BY WALLIN — DATE 17 MAR '59
CHECKED BY J. CLEMENT — DATE 3-18-59
APPROVED BY H Clement — DATE 3-18-59

TITLE
CABLE—
AC-DC CONVERTER TO 100 MV SERIES 20 OR SERIES 30

NON-LINEAR SYSTEMS INC.
DEL MAR AIRPORT
DEL MAR, CALIFORNIA

DRAWING NUMBER
15004-076
SCALE
WT.
SHEET 2 OF

REVISIONS				
1		F-1 WAS 3 AMP, STANDARD; REMOVED CODE TYPE DESIGNATION	5-12-59	



	OFF	DC	VAC-1000	VAC-100	VAC-10
K-1	OFF	OFF	OFF	OFF	ON
K-2	OFF	OFF	OFF	ON	OFF
K-3	OFF	ON	OFF	OFF	OFF
K-4	OFF	OFF	OFF	OFF	ON
K-5	OFF	OFF	ON	OFF	OFF
K-6	OFF	ON	ON	ON	ON

18044 SHEET 2

1

5. ALL CAPACITOR VALUES IN MICROFARADS.

4. ALL RESISTOR VALUES IN OHMS, ½W, ±10%

3. MODEL 125B ONLY USES ADDITIONAL FRONT PANEL CONNECTORS (XLR3-14 INPUT & XLR3-13 OUTPUT) IN PARALLEL WITH J-11 & J-12.

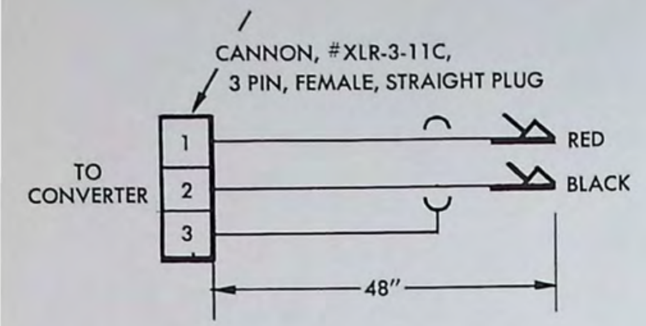
2. LOW FREQUENCY ADJUSTMENTS 100 cps OR LESS.

1. HIGH FREQUENCY COMPENSATION ADJUSTMENTS 3KC TO 10KC.

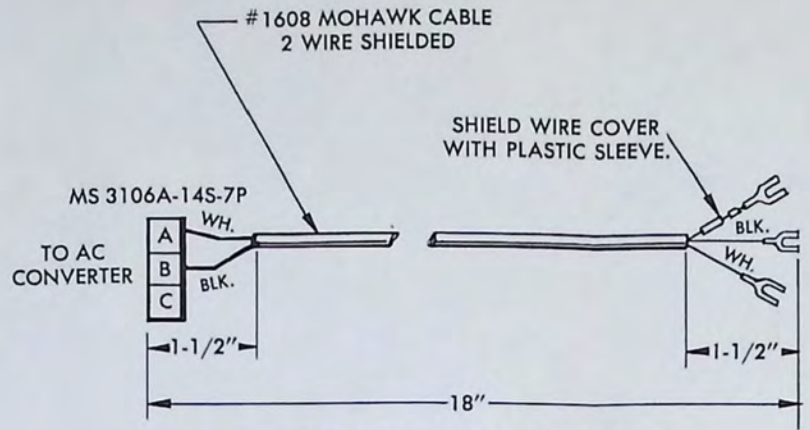
NOTES: UNLESS OTHERWISE SPECIFIED

DRAWN BY A.E. WALLIN	DATE 6 APR 59	TITLE: SCHEMATIC AC-DC CONVERTER	NON-LINEAR SYSTEMS INC. DEL MAR AIRPORT DEL MAR CALIFORNIA
CHECKED BY D. Foley	DATE 4-24-59	MODEL 125 A, B, & C	DRAWING NUMBER 18044
APPROVED H. Clement	DATE 4-24-59	SCALE / WT	SHEET 2 OF

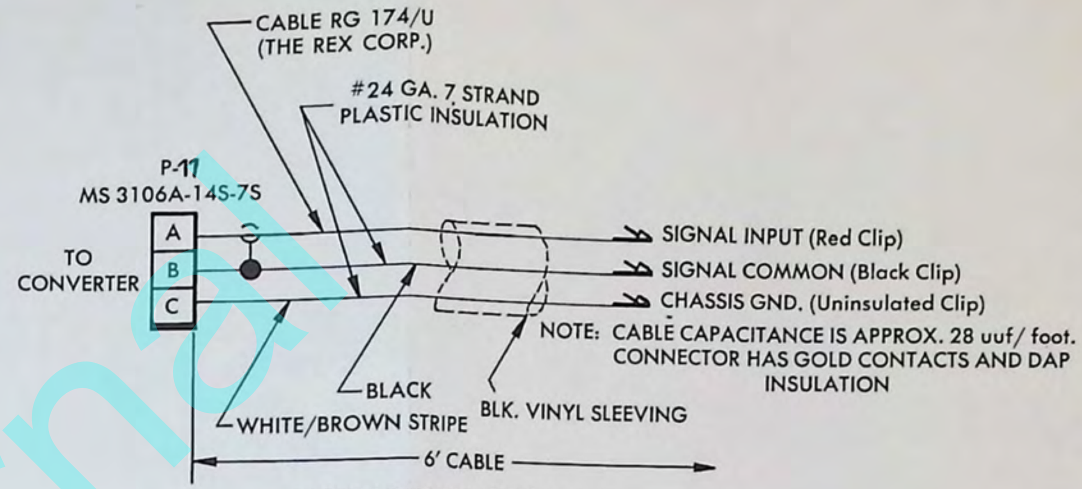
SCHEMATICS-INTERCONNECTING CABLES



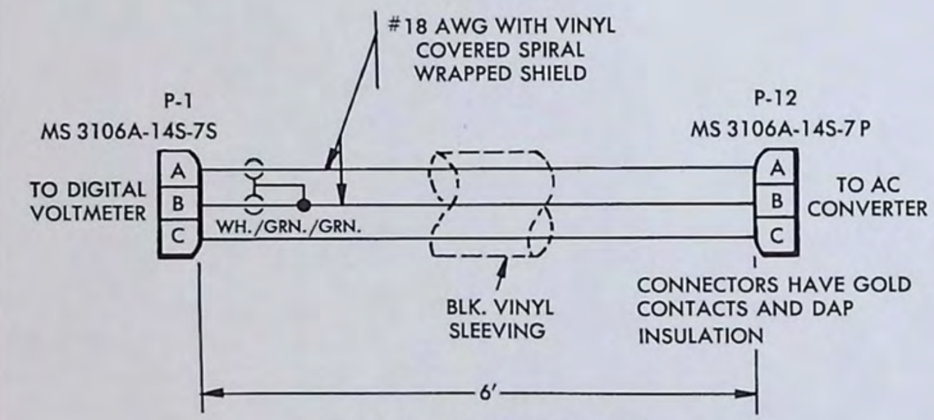
CABLE ASSEMBLY #11271-018



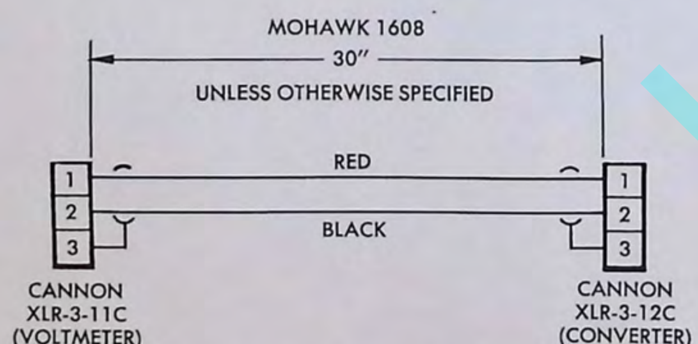
CABLE ASSEMBLY #15004-082



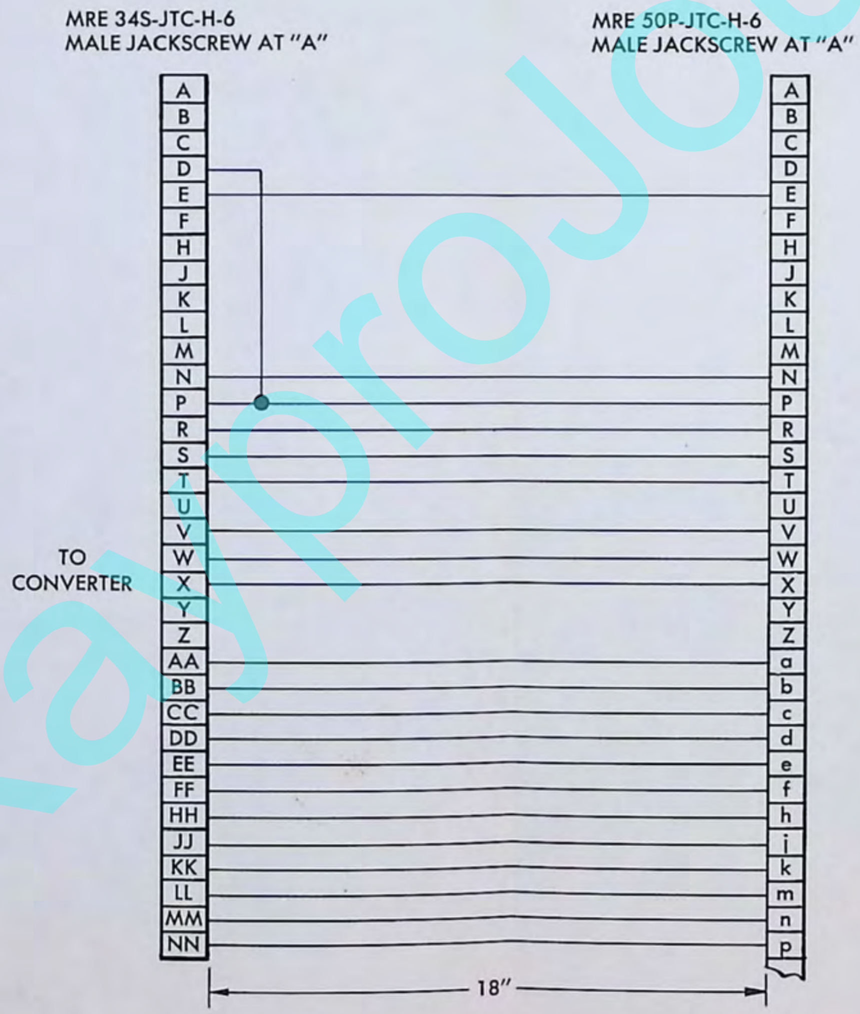
CABLE ASSEMBLY #15004-075



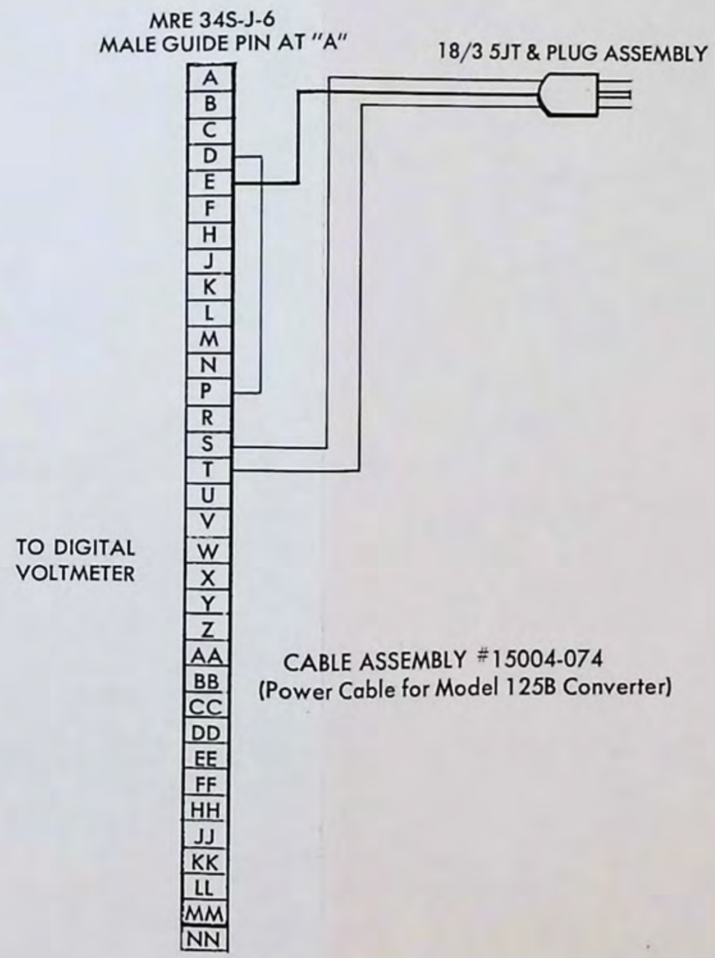
CABLE ASSEMBLY #15004-068



CABLE ASSEMBLY #15004-060



CABLE ASSEMBLY #15004-73



CABLE ASSEMBLY #15004-074
(Power Cable for Model 125B Converter)

NON-LINEAR SYSTEMS, INC.
Del Mar, California

TECHNICAL INFORMATION BULLETIN

CALIBRATING AC DIGITAL VOLTMETERS

INTRODUCTION

The method that is generally accepted for calibrating the most precise AC voltmeters is a technique developed by F. L. Hermach at the National Bureau of Standards (see Reference). It is called the transfer thermocouple method, because the reading of accurate DC voltage measuring devices standardized against cadmium-mercury standard cells, is transferred to AC measurements. In this method of measuring AC voltage, the unknown AC is supplied to the heater of an instrument thermocouple, and the generated thermoelectric potential is measured by a millivoltmeter. The thermocouple heater is then connected to a DC power supply, and the voltage varied until the millivoltmeter reads the same thermoelectric potential as it did when the unknown AC was applied to the heater element. Absolute accuracy of the millivoltmeter is not important, but very fine resolution and repeatability are. The DC power supply voltage is then accurately measured and its value is, by definition, the true rms value of the AC voltage.

NLS PROCEDURE

All NLS AC-DC converters are calibrated against a Hermach-Engelhard Transfer Volt Ammeter. The NLS Hermach-Engelhard instrument has been certified by the National Bureau of Standards to plus or minus 0.05%. A variable turns ratio transformer accurate to plus or minus .001% is used to cover different ranges. Step by step instructions for calibration for specific models manufactured by NLS are included in each instrument's handbook.

EQUIPMENT USED

The calibration setup used at NLS is shown in Figure 1. The Hermach-Engelhard Transfer Volt Ammeter, which has ranges from 15 to 300 volts, is certified by NBS from 20 to 20,000 cps. The AC voltage source used for calibration must be stable enough to permit transferring the DC reading to AC without significant voltage output change. Also, harmonic distortion must be low, for the AC digital voltmeter reads in proportion to the waveform average value, but is normally calibrated in terms of the rms value of a pure sine wave. The power supply must cover the voltage and frequency range required with enough power to drive the thermocouple. NLS uses a special oscillator with a 0.05% maximum harmonic distortion, 0.01% short term drift, 6 watts maximum power output. 0.05% harmonic distortion produces much less than 0.1% error. An accurate attenuator is connected at AA in Figure 1 to extend the range. The Gertsch variable turns ratio transformer is used for this purpose and for checking that the AC digital voltmeter's 10, 100 and 1,000 volt scale multipliers are adjusted correctly.

SUBSTITUTED EQUIPMENT

If the customer desires to calibrate AC digital voltmeters but does not have Hermach-Englehard equipment, a Weston type V-I (insulated bead) instrument thermocouple and a millivoltmeter with high resolution and repeatability can be used. In the absence of thermocouple equipment, a precision laboratory AC voltmeter of the dynamometer type can be used for less accurate tests and over a restricted frequency range.

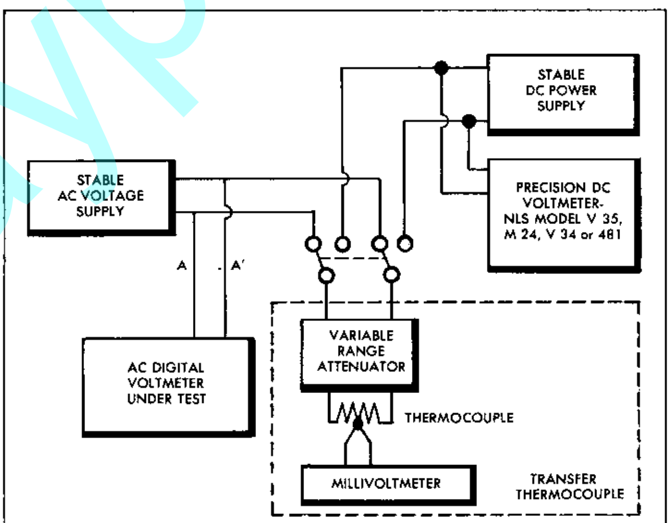


FIG. 1 - CALIBRATING AC DIGITAL VOLTMETERS BY THE TRANSFER THERMOCOUPLE METHOD

FIGURE 1

Calibrating AC Digital Voltmeters By The Transfer Thermocouple Method

References: Hermach & Williams - Multirange, A.F. Thermocouple Insts. Research Paper 2494 - U.S. Gov't Printing Office (bound in Vol. 52, Journal of Research, N.B.S.) - Hermach - Thermal Converters as Transfer Standards, Research Paper 2296 - U.S. Gov't Printing Office (bound in Vol. 48, Journal of Research, N.B.S.)