UNION SWITCH & SIGNAL
645 Russell Street
Batesburg, SC 29006

Service Manual 6134

Operation, Installation and Maintenance

AFO-IIC

Audio Frequency Overlay System

Transmitter N451052-29XX
Receiver N451052-31XX
Track Coupling Unit N451052-190X

June 1985

An ANSALDO Signal Company

Revision Index

This service manual supersedes all previously issued manuals. Please destroy all outdated manuals.

Revision	04/81
Revision	12/84
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SECTION I
GENERAL INFORMATION

1.1 PURPOSE

This manual describes the principles of Audio Frequency Overlay (AFO-IIC) track circuits and provides application information for the AFO-IIC equipment. This information is essential for planning AFO-IIC installations. It includes track circuit data necessary for laying out track circuits and frequency allocation rules which are necessary to provide optimum efficiency of operation.

1.2 DESCRIPTION

1.2.1 General

The AFO-IIC is designed to provide train detection in territories without insulated rail joints, so long as certain warnings and application rules are observed. These are described in Sections I and II of this manual. AFO-IIC can be used for highway crossing application or for continuous train detection in signal systems. The AFO-IIC Transmitter signal is amplitude-modulated to provide immunity to noise in the rails. All AFO-IIC Transmitters and Receivers are fully transistorized and operate from a dc power supply ranging from 9.5 to 16.2 volts. The term "audio frequency" refers to the frequencies within the audio range (20-20,000 Hz). The term "overlay" refers to the AFO signal superimposed or overlaid on the existing track circuit.

All circuitry in the transmitter and receiver units is mounted on printed circuit boards. The boards are hard-wired to external terminals and enclosed in sheet steel housings designed for shelf, wall or rack mounting. AAR terminal strips are provided for external circuit connections.

1.2.2 Track Circuit Operation

The AFO track circuit detects the presence of a train through loss of the audio frequency signal, which is shunted by the train axles. This is shown in Figure 1-1. The track circuit is composed of a transmitter, receiver and receiver relay. The transmitter introduces an audio signal of a specific assigned frequency into the track through two wires connected directly to the rails. This point defines one end of the AFO track circuit. The receiver only responds to a specific assigned frequency. It is also connected to the rails with two wires; this point defines the other end of the AFO track circuit. Upon receiving the proper frequency, the receiver detects, amplifies, and rectifies the signal to provide an output to operate an external relay. The contacts of the relay are then employed in the same fashion as conventional track relay contacts. The transmitter and receiver require a dc power source for operation.

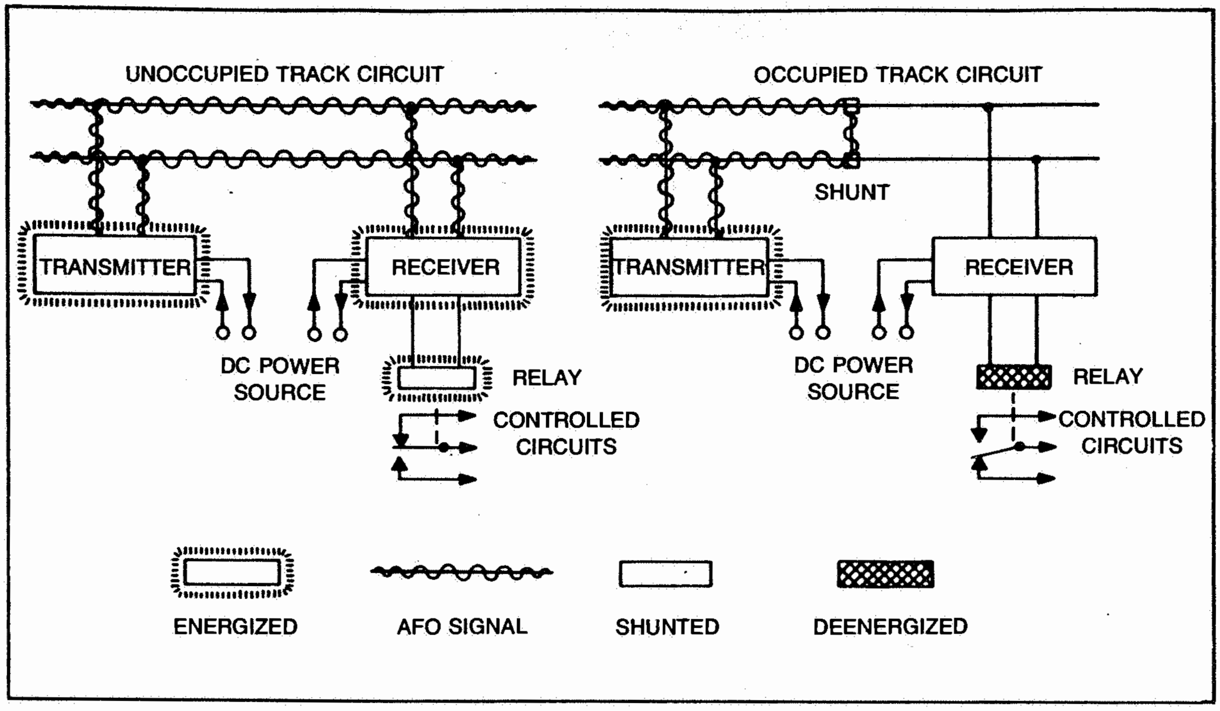

Figure 1-1. Typical AFO-IIC Track Circuit Operation

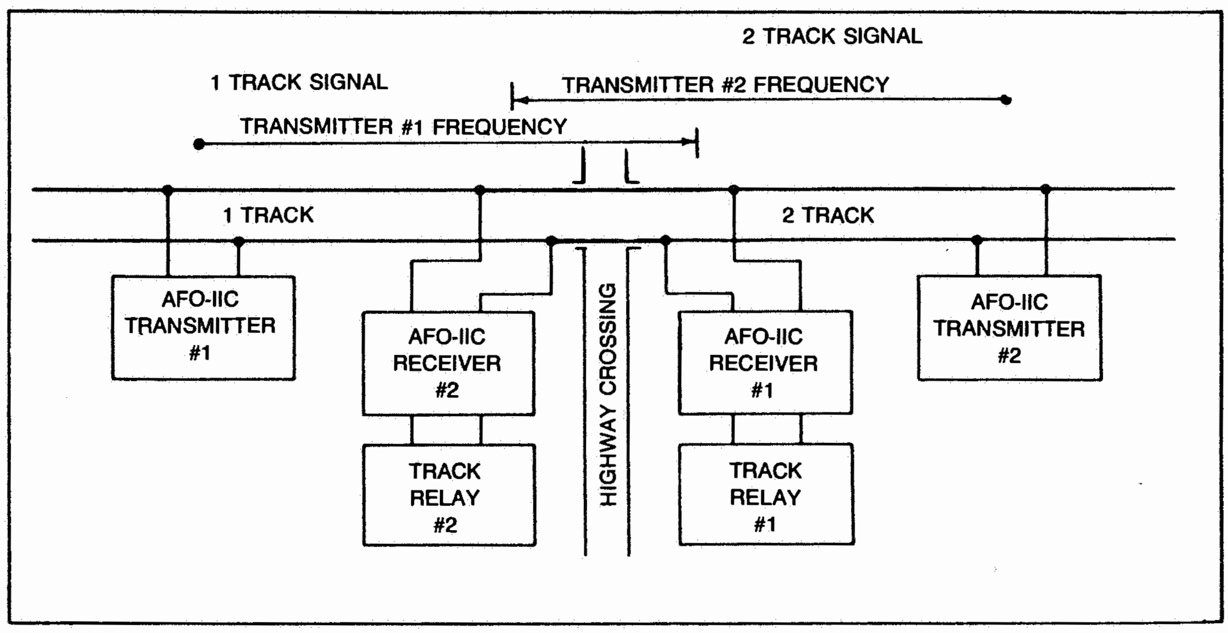

Figure 1-2. Typical AFO-IIC Highway Crossing Layout With Overlapping Track Circuits

A series of AFO-IIC track circuits can be superimposed on a track section (see Figure 2-3). Each track circuit is designed to operate independently without interference from other AFO-IIC or dc track circuits. This is most important where adjacent highway crossings have overlapping approach limits. Also, it allows an overlap at the crossing for an island circuit, as shown in Figure 1-2.

1.2.3 Circuit Protection

Surge protection is provided within the receiver and transmitter for both the dc line and track lead inputs. Refer to Section 2.6 for lightning protection requirements.

Reverse polarity protection is also included. If battery polarity is accidentally reversed, a protective fuse will blow which disconnects the unit from the battery supply. This is intended to prevent power loss to other equipment.

1.3 AFO-IIC RECEIVER (N451052-31XX)

1.3.1 General

The AFO-IIC Receiver operates over a dc battery voltage range of 9.5 to 16.2 volts. In case of battery failure, the receiver is designed to not be damaged from the battery charger rectifier or cause the receiver relay to be falsely energized. A sensitivity adjustment is built into the receiver unit to obtain the proper shunting characteristics for each track circuit. The AFO-IIC Receiver is housed with all circuit components mounted on two printed circuit boards: Input Filter and Demodulator-Relay Driver. Both boards are mounted on the top plate, by means of a support bracket, and enclosed within the housing. The design of the AFO-IIC Receiver provides increased immunity from potential traction control choppers and traction power supply interference in electrical railroads. The receiver design also provides increased immunity from radio interference.

1.3.2 Input Filter Board (N451522-53XX) (See Figure 1-3)

The signal from the track is applied to a high selectivity band-pass filter on the Input Filter board. Its input is a low impedance, series-tuned circuit which rejects dc or low frequency ac voltages present from any existing track circuit. The filtered AFO signal is then applied to a gain adjustment circuit which includes a "sensitivity" potentiometer. The gain is adjusted at installation to establish the track circuit shunting sensitivity. The signal is then applied to a tuned step-up transformer, then demodulated by the envelope detector. Its output is then fed into the impedance matching circuit to provide a low impedance source to the modulation band-pass filter on the next board.

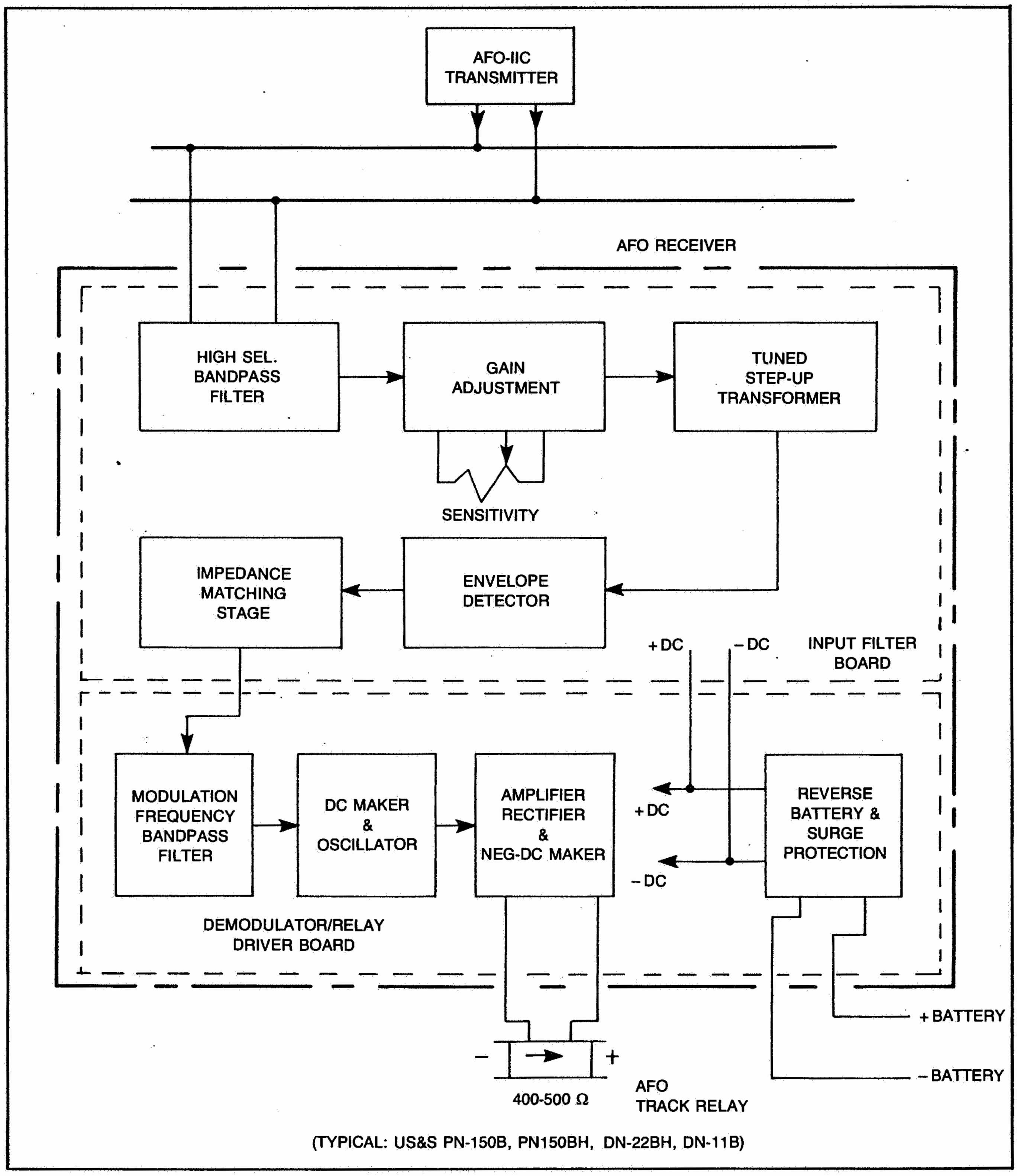

Figure 1-3. AFO-IIC Receiver Block Diagram

1.3.3 Demodulator/Relay Driver Board (N451522-68XX) (See Figure 2-3)

At the Demodulator/Relay Driver board, the recovered envelope of the signal is filtered to pass only the assigned modulation frequency. A negative dc voltage is developed from the rectified output to power a high frequency oscillator which acts as a level detector. The output of the oscillator is amplified and again rectified to develop a negative dc voltage to drive the relay.

Also included on the Demodulator/Relay Driver board is power surge protection circuitry at the battery connection to protect the solid state electronics against voltage spikes. Reversed battery protection is also included.

1.3.4 Specifications

Input Voltage:	9.5 - 16.2 Vdc
Input Current:	0.07 amp. at 12 Vdc
Output Voltage: (400 ohm load)	5.05 Vdc minimum (with 3 mV RMS input signal and 9.5 volts battery)
Signal Sensitivity:	3.0 $\pm$ 0.3 millivolts RMS minimum detectable signal (14.1 $\pm$ 2.0 millivolts P-P during the period of the modulation cycle when the signal is at a maximum)
Input Impedance (Track):	1.25 ohm at center of assigned frequency (nominal)
Output Load:	400 or 500 ohm Relay
Bandwidth:	-3 db at +4.0% of assigned frequency
Operating Frequencies:	Refer to Table 3-1
Temperature Range:	$-40^{o}C$ to $+71^{o}C$ ($-40^{o}F$ to $+160^{o}F$)
Surge Protection:	Built-in
Dielectric Breakdown Test	3000 Vdc rms at 60 Hz between track leads and input (battery) leads.

1.4 RECEIVER RELAY

A 400 or 500 ohm, biased dc relay is typically used as a receiver relay for the AFO-IIC system. Refer to section 2.2 for recommended relays and application data.

1.5 AFO-IIC TRANSMITTER (N451052-29XX)

1.5.1 General

The AFO-IIC Transmitter has a fixed output. It operates on a dc battery voltage range of 9.5 to 16.2 volts. The modulated signal is designed to provide noise immunity for the circuit and reduce battery consumption by the transmitter. The AFO-IIC Transmitter contains one printed circuit board: Transmitter.

1.5.2 Transmitter Board (N451522-45XX) (See Figure 1-4)

The Transmitter board accomplishes four functions, including generation of the basic carrier frequency, generation of the modulation rate frequency, summing of the carrier and modulation signals and voltage amplification.

The fundamental carrier signal is generated at the carrier oscillator and is coupled to a summing circuit. A modulation oscillator generates the modulating signal. It is coupled to the summing circuit where it causes the carrier signal to increase and decrease in amplitude at the modulation rate. The signal, after being coupled through a buffer stage, is of very low energy level and requires several stages of current and voltage amplification. The final stage of amplification transforms the high impedance output of the emitter follower and provides low impedance coupling to the track through a two transistor push-pull power amplifier. The amplifier has at its output a series resonant circuit. The series-resonant circuit allows easy passage of the modulated carrier frequency signal and inhibits passage of any unwanted signals, such as harmonics.

1.5.3 Specifications

Input Voltage:	9.5 - 16.2 Vdc
Input Current: (2 ohm output load)	0.40 ±.06 amp. at 12 V input
Output Voltage: (2 Ohm(load, 12.0V battery)	5.0 ± 0.4 VP-P during "ON" period of modulation.
Output Impedance: (Nom. at center of assigned frequency)	1 Ohm
Operating Frequencies:	Refer to Table 3-1
Temperature Range:	-40°C to +71°C (-40°F to +160°F)
Surge Protection:	Built-in
Min. Ballast Resistance:	3 ohm/1000 Ft.

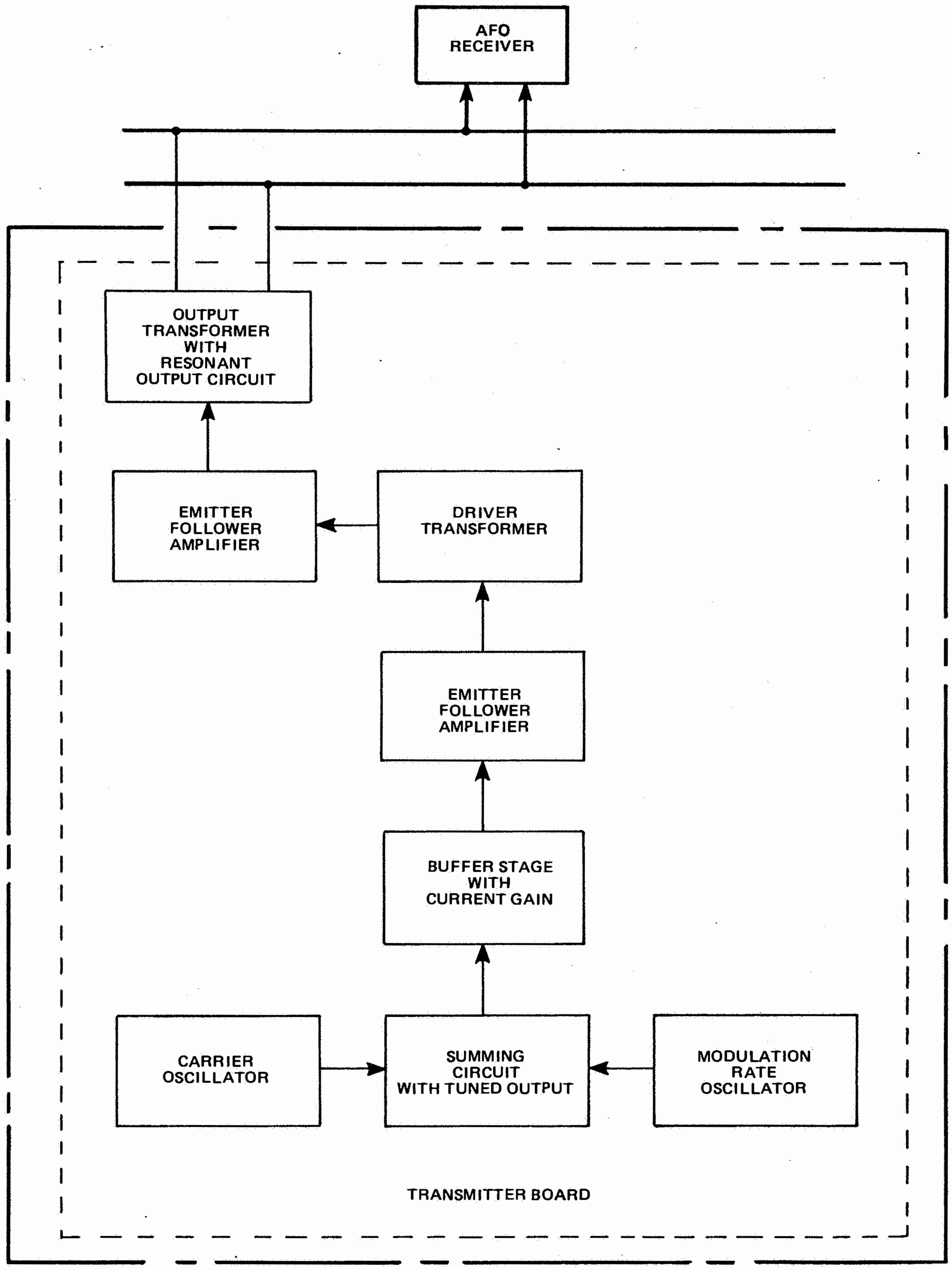

Figure 1-4. AFO-IIC Transmitter Block Diagram

1.6 AUXILIARY EQUIPMENT

1.6.1 Track Coupling Units (N451052-19XX)

A Track Coupling unit is used when the AFO signal must be passed around insulated joints and the existing track circuit energy must be blocked. This unit uses transformer-coupling to pass the AFO signal to the next track section. Redundant blocking of dc passage is accomplished by both the transformer and series components to provide vitality of the system. When insulated joints need to be traversed, the frequency of an AFO-IIC transmitter-receiver pair on either side of the joint must be the same as the coupling unit.

Four coupling units are available. Each is capable of passing several different distinct frequencies (three units pass six frequencies, one passes four frequencies; see Figure 3-2). The units have tuned taps for each frequency in its group. Thus, a different unit is required for each frequency to be passed around the insulated joints. The frequency-determining taps are located inside the unit and must be connected to the proper taps as determined by the selected operating frequency. The Track Coupling Unit has the same housing and mounting options as the AFO-IIC receiver and transmitter. Table 3-1 contains general part number references for the Track Coupling Units.

1.6.2 Blocking Reactor

The Blocking Reactor blocks the AFO signal while passing dc and low frequency ac. Reactor N451036-0302 is recommended for this application. It has a dc resistance of 0.01 ohm and a current rating of 7 amperes. This reactor may be mounted on a relay rack in a PN-250 space or on a wall or shelf. Dimensions are 8" x 5" mounting plate with a depth of 3-5/8". Refer to section 2.4 for various applications to AFO-IIC track circuits.

WARNING

AFO EQUIPMENT IS DESIGNED TO OPERATE OVER A NORMALLY EXPECTED VARIETY OF ENVIRONMENTAL CONDITIONS. HOWEVER ELECTRIC PROPULSION EQUIPMENT EMPLOYING PHASE CONTROL OR CHOPPER CONTROL MAY CREATE AN EXCESSIVE AMOUNT OF ELECTROMAGNETIC INTERFERENCE IN THE AUDIO SPECTRUM, THUS CAUSING IMPROPER AND POTENTIALLY UNSAFE OPERATION OF THE AFO RECEIVERS.

SIMILARLY, THE OPERATION OF HAND-HELD RADIO TRANSMITTERS IN THE VICINITY OF OPEN WAYSIDE HOUSINGS MAY CAUSE SUFFICIENT RADIO INTERFERENCE TO RESULT IN POTENTIALLY UNSAFE OPERATION OF AFO AND OTHER ELECTRONIC DETECTION EQUIPMENT.

Proper application of AFO equipment under the conditions described above requires special engineering analysis. Contact the US&S District Sales representative to discuss possible audio frequency interference of the AFO equiupment in the customer's application.

SECTION II
APPLICATION

2.1 FREQENCY SELECTION

2.1.1 General

The AFO-IIC System provides transmitter and receiver units with all frequencies between 800 and 5000 Hz. The frequency spectrum is divided into 20 groups, as shown in Table 2-1. The desired frequencies of the transmitter and receiver units are selected in accordance with unit part numbers. Refer to section A.1.1 for these part numbers.

WARNING

> THERE MUST BE At LEAST A 25% SEPARATION BETWEEN THE ASSIGNED FREQUENCIES OF ANY EQUIPMENT CONNECTED TO THE TRACK, WITHIN A COMMON BLOCK, BETWEEN INSULATED JOINTS. IN A TWO-TRACK SYSTEM, THE FREQUENCY SEPARATION OF TRACK 1 AND TRACK 2 UNITS MUST NOT BE LESS THAN 5%. OTHERWISE, A HAZARD MAY BE CREATED THAT COULD LEAD TO UNSAFE OPERATION.

Ideally, frequency selection of AFO-IIC units should be staggered.

When designing an AFO-IIC system, observe the following rules:

1. Obtain optimum separation from the sum and difference frequencies of assigned AFO-IIC frequencies.

2. Avoid harmonics up to the fifth harmonic of AFO-IIC frequencies.

3. Minimize harmonic mixing and the mixing of harmonics with the assigned AFO-IIC frequencies.

4. Obtain optimum separation from the 60 cycle power frequency and its harmonics and the mixing of these with AFO-IIC frequencies.

2.1.2 Compatibility with Motion Monitor

Table 2-2 shows the frequency compatibility between some preselected AFO-IIC and Motion Monitor frequencies. Other AFO-IIC frequency allocations must follow these rules:

1. Avoid AFO frequencies which are a harmonic of the Motion Monitor frequency, up to the seventh harmonic.

2. Obtain optimum separation from the 60 cycle power frequency and its harmonics, and the mixing of these with Motion Monitor frequencies and its harmonics.

Table 2-1. Basic Audio Frequency Ranges

Frequency Range Designation	AFO-IIC Coupling Unit Frequency	Frequency Range	Modulation Rate
FR 1		800-875	18
FR 2	870, 885, 930, 945	876-960	18
FR 3	980, 1050	961-1055	22
FR 4	1120	1056-1155	22
FR 5	1180, 1215	1156-1265	22
FR 6	1285, 1330	1266-1385	27
FR 7	1420, 1520	1386-1520	27
FR 8		1521-1665	27
FR 9	1660	1666-1825	39
FR 10	1860, 1945	1826-2000	39
FR 11	2140	2001-2190	39
FR 12	2365	2191-2400	49
FR 13	2540	2401-2630	49
FR 14	2720	2631-2885	49
FR 15		2886-3160	68
FR 16	3360, 3410	3161-3465	68
FR 17		3466-3800	68
FR 18		3801-4165	94
FR 19		4166-4560	94
FR 20		4561-5000	94

Table 3-2. Selected Compatible Frequencies of AFO-II and Motion Monitor Equipment

AFO-II Frequency	Motion Monitor Frequency
930 and 3410 Hz	207 Hz
1050 and 3360 Hz	230 Hz
885 and 1860 Hz	390 and 570 Hz
1330 and 3360 Hz	390 and 570 Hz
1050 and 2540 Hz	390 and 570 Hz
1120 and 2720 Hz	405 and 630 Hz
2140 and 1420 Hz	405 and 630 Hz
930 and 3410 Hz	405 and 630 Hz

2.1.3 Compatibility With Coupling Units

Compatible AFO-IIC and Track Coupling Unit frequencies are shown in Table 2-1. Frequencies not compatible with the AFO-IIC Track Coupling Units must be applied in a track section where it is not necessary to bypass an insulated joint.

2.1.4 Basic Application Rules

Certain basic rules must be followed in the application of AFO-IIC track circuit equipment to ensure maximum effectiveness and security. These are as follows:

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1. Do not repeat the same frequency on the same track unless the track circuits are separated by two pairs of insulated joints.

   a. If a coupling unit is used to bypass a set of insulated joints, these joints may not be counted in applying Rule 1 above.

   b. Frequency separation between adjacent AFO-IIC pairs in the same block must be at least 25% apart.

2. The same AFO-IIC frequency must not be located adjacent on parallel tracks.

3. When more than one highway crossing is involved in an AFO layout, a ripple-free power supply must be provided for the transmitters.

Surge-Ripple Filter N451036-0702 is available for insertion between the transmitter and the power supply (refer to section 2.7).

In selecting and applying the frequencies, the required length of the track circuit must also be considered since the AFO signal attenuation in the track circuit is directly proportional to the frequency. Figure 2-1, a block length versus frequency curve, shows the maximum effective block length permitted for the AFO-IIC equipment.

NOTE

> For each coupling unit used in an AFO-IIC track circuit, the effective length of that track circuit is reduced by 500 feet.

Figure 2-1 represents the maximum lengths for adjusting the track circuit at 3, 5 and 20 ohms ballast resistance and does not consider the increase in receding ringing distance resulting from a drop in ballast resistance.

2.2 RECEIVER RELAY

The AFO-IIC receiver incorporates an electronic level detector which is designed to simplify relay requirements. US&S relays DN-22BH or the PN-150BH are recommended for the AFO-IIC receiver relay. However, other 400 to 500 ohm relays such as the US&S PN-150B (N322500-701) or the DN-11B (N274069) can be used with the AFO-II equipment.

2.3 TRACK COUPLING UNITS

Three Track Coupling Units are provided to pass any one of the six frequencies in the group for which either is tuned and connected, (refer to Table 2-1). A fourth Track Coupling Unit is capable of passing four frequencies. All other frequencies are rejected. Refer to section 6.X for part number and frequency cross-references. See Figures 3-2 and 3-3 for coupling unit wiring connections.

NOTE

> Since each Track Coupling Unit has tuned internal taps for each frequency in its class, one unit is required for each frequency passed around the insulated joint pair.

Each time an AFO-IIC signal is coupled around insulated joints, the effective length of the AFO track circuit is reduced by an average of 200 to 300 feet, depending on the location of the unit within the track circuit.

Due to severe restriction of effective track circuit lengths, coupling units cannot be used to bypass insulated joints in the higher frequencies.

2.4 BLOCKING REACTOR

2.4.1 General Application

Blocking Reactors are used to block the AFO signal while passing dc and low frequency ac. For example; to prevent shunting the AFO signal through the battery, a Blocking Reactor must be installed in series with one lead of an existing dc battery rail connection which occurs near an AFO-IIC track circuit. The purpose of the reactor is to block the AFO signal while passing dc and low frequency ac. See View "A" of Figure 2-3. This is not necessary if an AFO-IIC track circuit occurs near the relay end of an existing dc track circuit. The coils in the relay will provide the necessary impedance to block the AFO signal. See Figure 2-3 for other applications.

2.4.2 AFO and Microcode Compatibility

In applications where Microcode is overlayed on AFO-IIC track circuits, a blocking reactor may be required to prevenet shunting the AFO signal. When the Microcode is confined within the AFO track circuit, blocking reactor No. 1 listed below is recommended. Where the Microcode in a particular application is operating near the upper limit of its distance range (see Microcode application service manual No. 6195), blocking reactor No. 2 listed below is recommended. The blocking reactor is installed in series with one of Microcodes track leads.

The determination when to use blocking reactors in Microcode applications outside the confinement of the AFO track circuit is decided by the following steps:

1. By knowing the frequency of the adjoining AFO-IIC unit.

2. And by calculating the critical distance "D" (Diagram A) beyond which no reactor is required at a particular AFO frequency using the formula below:

$$D = \frac{1300}{\sqrt{f}} \quad \text{(in feet)}$$

Where f = KHz

Example: AFO-IIC frequency is 0.885 KHz

$$\text{Thus Distance } D = \frac{1300}{\sqrt{.885}} = 1382 \text{ feet}$$

This means that when a microcode is located within 1382 feet from either a AFO-IIC transmitter or receiver (885 Hz) it is required to have a reactor in series with one of its track leads.

Here again the selection of the No. 1 reactor is recommended. However if as described above, the block length of the Microcode is near its upper limit of its advertised distance range the use of No. 2 blocking reactor will suffice. In fact, if the Microcode distant requirement is really critical, two No. 2 blocking reactors may be paralleled when microcode is located at least $\frac{\text{"D"}}{2}$ feet from the adjacent AFO unit.

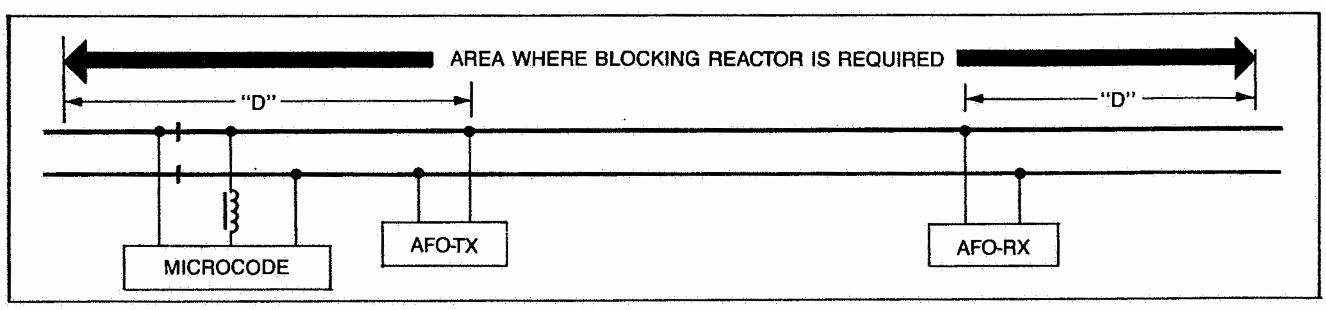


Diagram a - Microcode Application

Blocking Reactor No. 1
N451036-0302, inductance of 1.9 mh and has a DC resistance of 0.01 ohm.

Blocking Reactor No. 2
N451036-1701, inductance of 1.0 mh and has a DC resistance of 0.01 ohm.

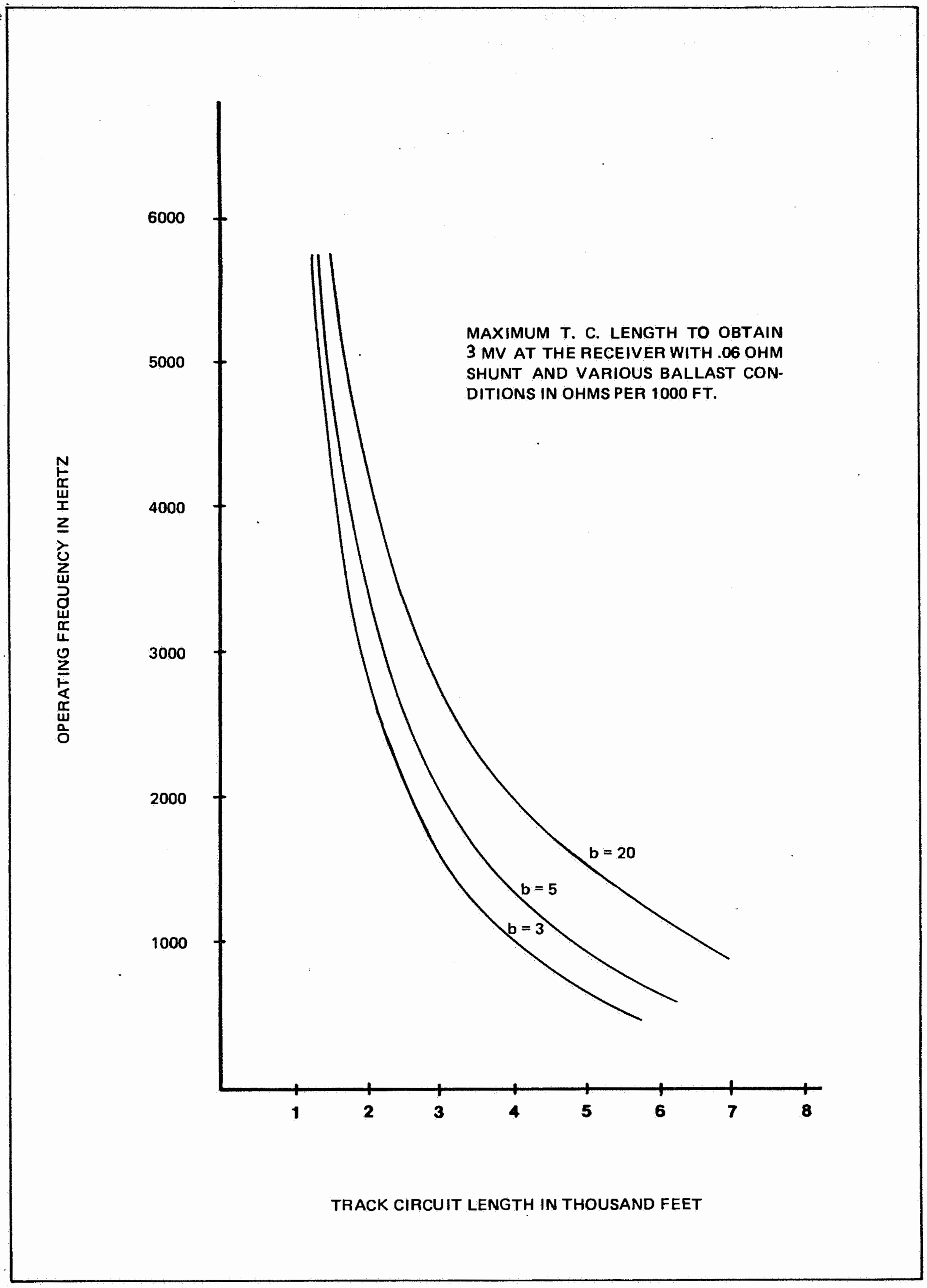


Figure 2-1. Maximum Block Length

The need for the reactor depends upon the impedance presented by the existing dc equipment, their leads, their distance from the AFO-IIC track circuit, and the AFO-IIC frequency employed. One reactor is effective for all AFO frequencies. Figure 2-2 shows the relationship between minimum impedance, AFO-IIC frequency, and distance. For example, if the AFO frequency is 1330 Hz and the distance is 200 feet, a reactor must be installed if the impedance in path A, B, C and D is less than 0.7 ohm.

Blocking Reactors may also be used for applications as shown in Views "B" to "D", Figure 2-3.

View "B" - Allows the dc track circuit to be shunted by a switch circuit controller without shunting the AFO signal.

View "C" - Defines the AFO track circuit at a specific point with insulated joints and allows the dc circuit to pass.

View "D" - Keeps the AFO signal out of the fouling circuit at a turnout.

2.5 TRACK LEADS AND POWER SUPPLY

Leads from the AFO-IIC units to the track should be arranged to minimize their series inductance. Unsheathed single wires may be used in pairs, provided that they are twisted, (3 twists per foot) or kept together within the same conduit. Metal-sheathed single wires should not be used. Sheathed wire or conduit is not required for AFO-IIC wiring within the wayside housing. A Transmitter and Receiver Unit of the same frequency should have its own leads to the track.

The battery charger rectifier leads should be wired directly to the battery and then to the power busses or equipment to prevent the battery from being removed from the circuit due to a broken wire, and to ensure a ripple-free power supply.

A resistor should never be placed in the power lead to a transmitter or receiver, since the total power lead resistance must be less than 0.15 ohm for transmitters and 0.5 ohm for receivers. If either of these values is exceeded, or if a signal (or ripple) greater than 0.5 volt peak-to-peak exists on the power leads, a surge-ripple filter must be employed.

The following total lead wire resistances are the maximum permissible for maximum track circuit length and minimum "receding ringing" distance:

1.	Transmitter to Rails	.15 ohm
2.	Receiver to Rails	0.15 ohm
3.	Receiver to Relay	25.00 ohms
4.	Battery to Receiver	0.5 ohm
5.	Battery to Transmitter	0.15 ohm
6.	Coupling Unit to Rails (Each End)	0.15 ohm

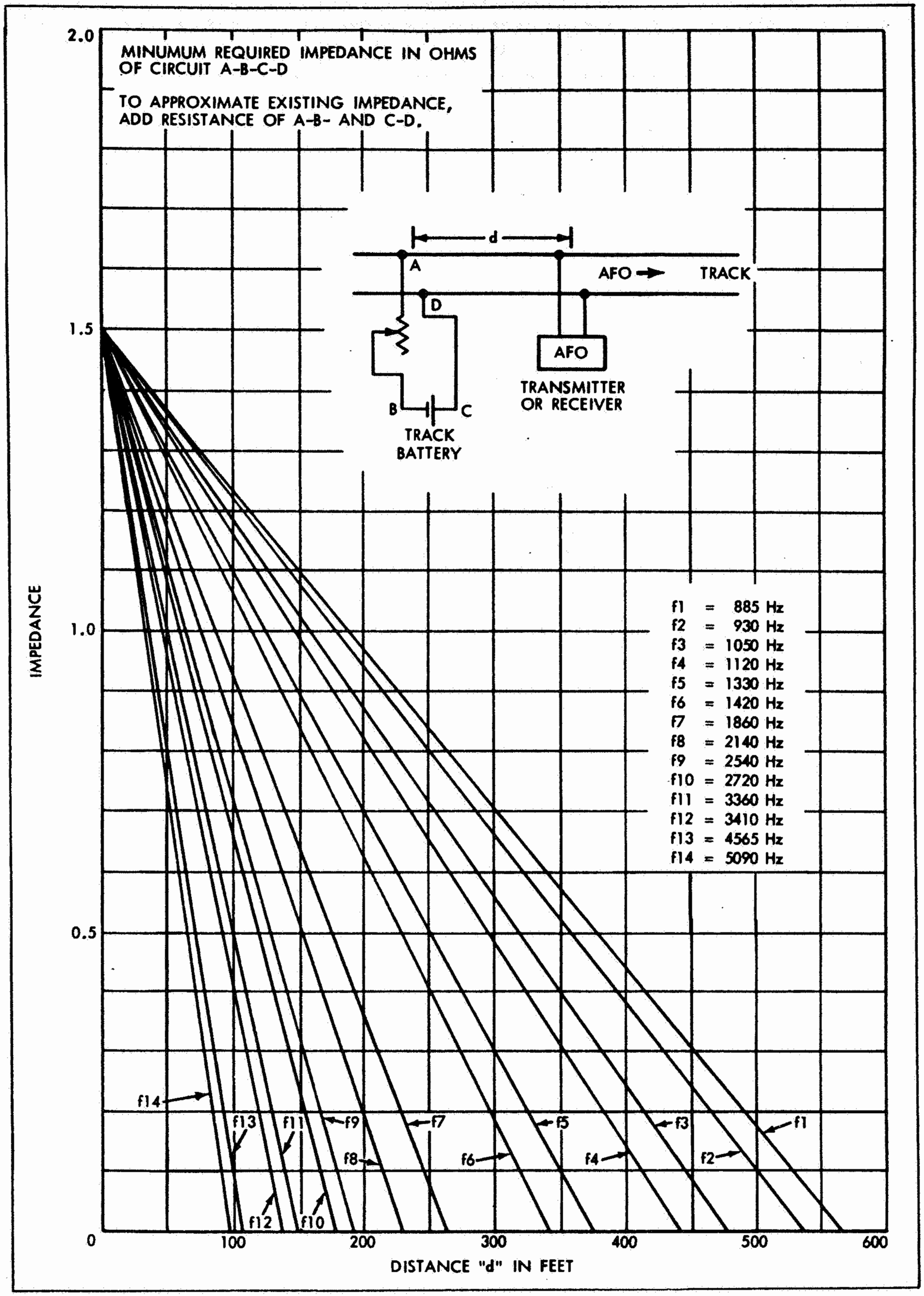


Figure 2-2. Requirements for Blocking Reactor

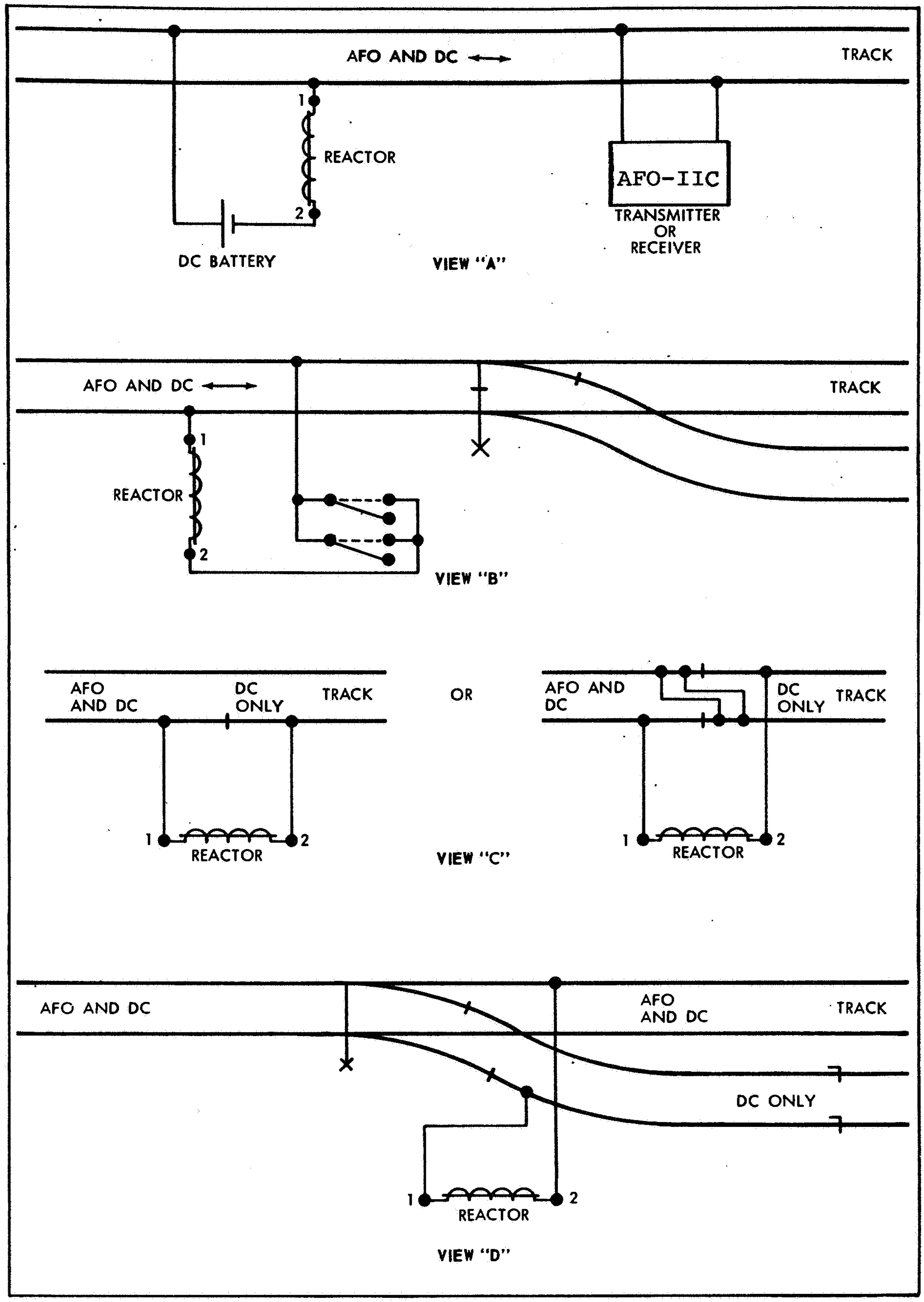


Figure 2-3. Applications of Reactor to AFO-IIC Track Circuits

2.6 LIGHTNING PROTECTION

2.6.1 General

In order to limit surge voltages from lightning, it is important to use suitable arresters between any points of exposure. This is best accomplished using a shunt arrester between the track leads to each unit and series arresters from each track lead to a common ground bus. The bus should be connected directly to the housing signal poles and all grounds at the location to limit the surge voltage between any connections on the equipment or between the equipment and the housing.

NOTE

Ground wires should be short and without sharp bends.

Each of the series arresters should limit the surge voltage across itself to less than 1500 volts (peak) to prevent the voltage between any two points from exceeding 3000 volts (peak).

2.6.2 Track Terminal Protection

Lightning damage can occur from surges entering the AFO-IIC units either through the track terminals or through the battery terminals. These terminals must be protected as follows:

The track terminals of each AFO-IIC Transmitter and Receiver should be protected by both series and shunt lightning arresters as shown in Figure 2-4 and the coupling unit as shown in Figure 2-5.

Reference 1 in these figures should be a US&S USGA Arrester with a minimum breakdown rating of 500 peak volts and a maximum rating of 1300 peak volts.

Reference 2 should be a US&S USGA Arrester with a minimum breakdown rating of 75 peak volts and a maximum rating of 200 peak volts.

Ground connections, reference 3, should be made to the common low voltage ground bus system that includes grounds at cases or houses. Make ground connections and jumpers with #6 AWG wire. Messenger wire or metallic sheath of cable, if used, may serve as tie-in between cases or houses.

2.6.3 Battery Line Protection

Although the AFO-IIC Transmitter and Receiver have built-in surge suppression, they require additional protection across the power supply. This is accomplished by using the USG Shunt Arrester, reference 2 of Figure 2-6, across the power leads to the AFO-IIC equipment.

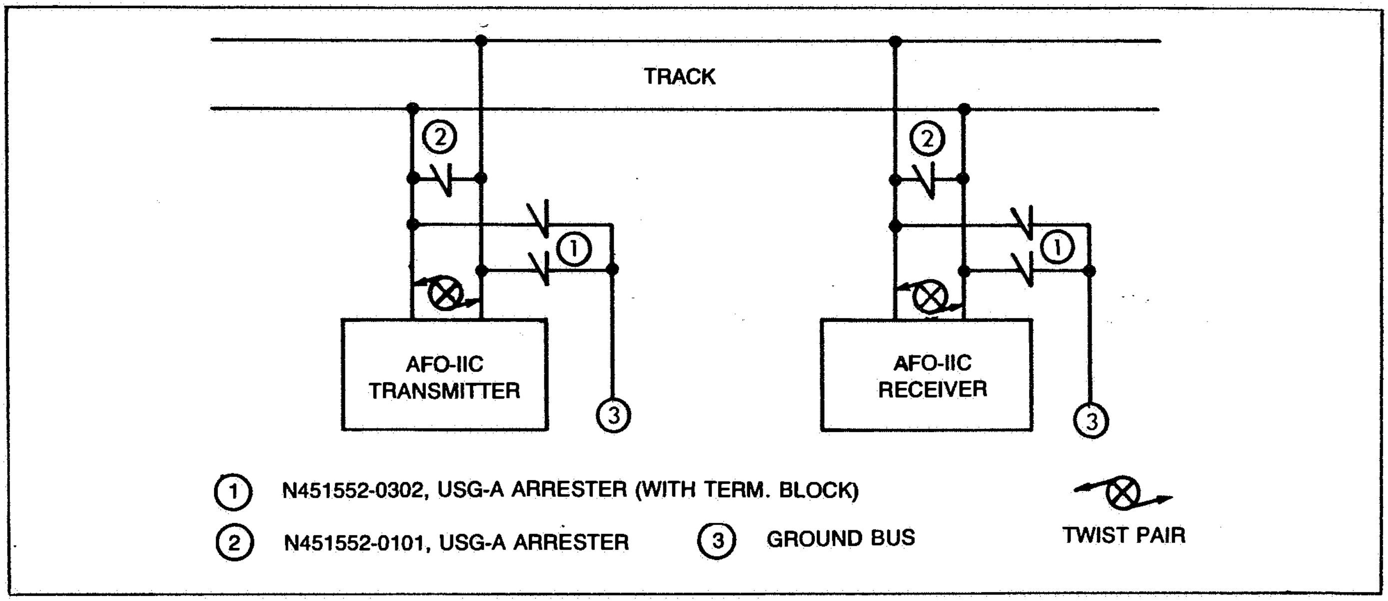


Figure 2-4. Track Lead Lightning Protection: Transmitter and Receiver

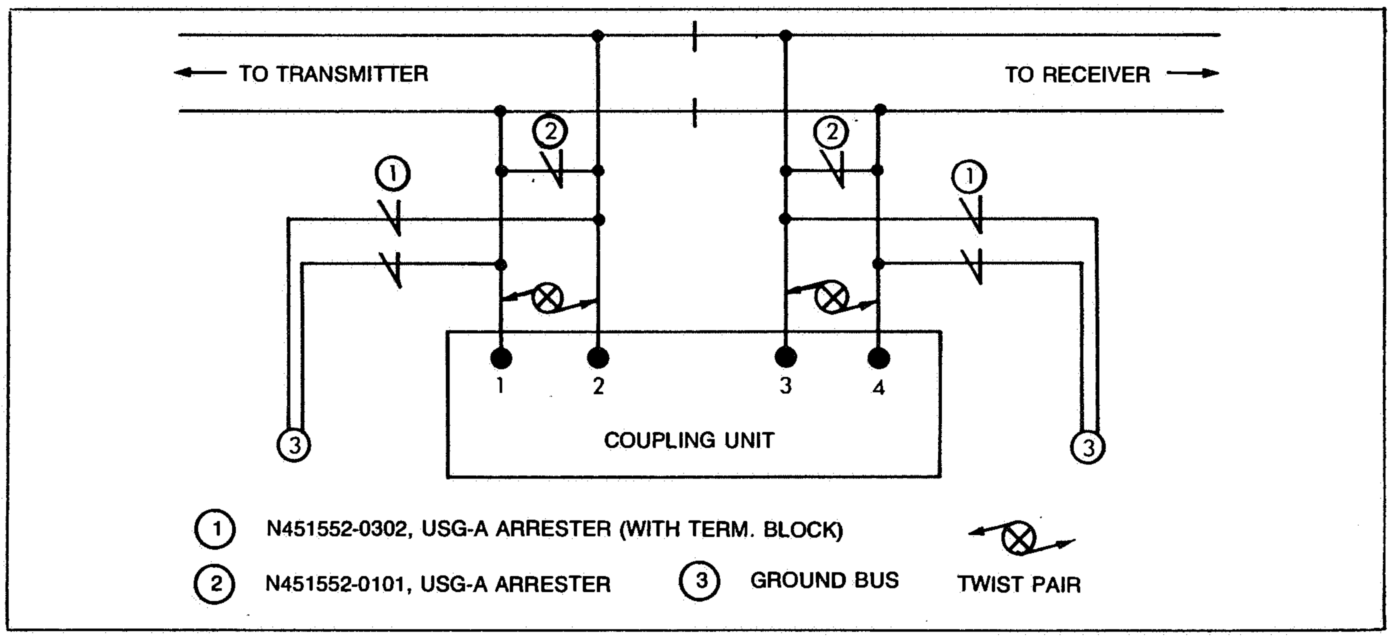


Figure 2-5. Track Lead Lightning Protection: Coupling Units and Connections

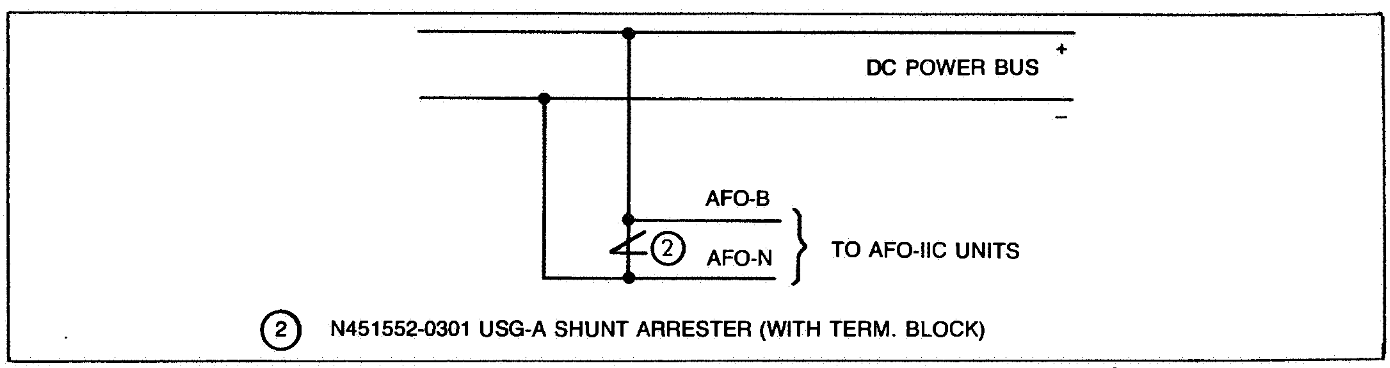


Figure 2-6. Power Supply Lightning Protection

2.7 SURGE-RIPPLE FILTERS

Normal operation of AFO-IIC Transmitters and Receivers directly from a rectifier is not recommended since reliability of filter components will decrease due to excessive ripple. If the battery supply has a ripple or an ac signal greater than 0.5V peak-to-peak, a surge-ripple filter must be used. If more than one filter is required because of current capacity, all transmitters should be connected to one filter and all receivers to another filter.

A transmitter and receiver of the same frequency should not be connected to the same surge-ripple filter, nor should they be connected to the same battery unless a surge-ripple filter is employed to isolate their power leads. This requirement is satisfied by placing a surge-ripple filter in the power leads to either unit, but preferably the receiver. When more than one transmitter/receiver pair is powered from the same source, connecting all the receivers to one filter (up to the filter's current capacity) will satisfy the requirement.

Refer to Table 6-1 for Surge-Ripple Filter part number.

SECTION III
INSTALLATION AND ADJUSTMENTS

NOTE

All AFO-IIC equipment must be installed in accordance with approved application plans.

CAUTION

LEAVE DC POWER FOR ALL AFO-IIC EQUIPMENT DISCONNECTED UNTIL INITIAL EQUIPMENT ADJUSTMENTS ARE COMPLETE, (section 3.2), OTHERWISE EQUIPMENT DAMAGE MAY RESULT.

3.1 WIRING CONNECTIONS

3.1.1 AFO-IIC Transmitter (See Figure 3-1)

1. Connect the positive and negative power supply to terminals #1 and #2, respectively. Make certain to observe correct polarity (+dc #1, -dc #2).

2. Connect the track leads to terminals #3 and #4.

3.1.2 AFO-IIC Receiver (See Figure 3-1)

1. Connect the positive and negative power supply to terminals #1 and #2, respectively. Make certain to observe correct polarity (+dc #1, -dc #2).

2. Connect the track leads to terminals #3 and #4.

3. Connect the + and - relay leads to receiver terminals #5 and #6, respectively. Make certain to observe correct polarity.

3.1.3 Track Coupling Units (See Figures 2-5, 3-2 and 3-3)

The Track Coupling Unit selection, groups 1, 2, 3 and 4 (refer to Table 3-1) is based on the class of the frequency for which it is used. Total track lead resistance should be kept below 0.15 ohm per pair. The coupling units should not be used within 100 feet of a receiver or transmitter. One unit is required for each frequency to be passed around the insulated joints.

Before connecting a coupling unit to the track, set the proper as frequency as follows:

1. Remove the unit from the sheet metal cover and locate the four wires on terminal strips (within the cover). The connections of these wires are used to set up desired frequency. See Table 3-1 and Figures 3-2 and 3-3.

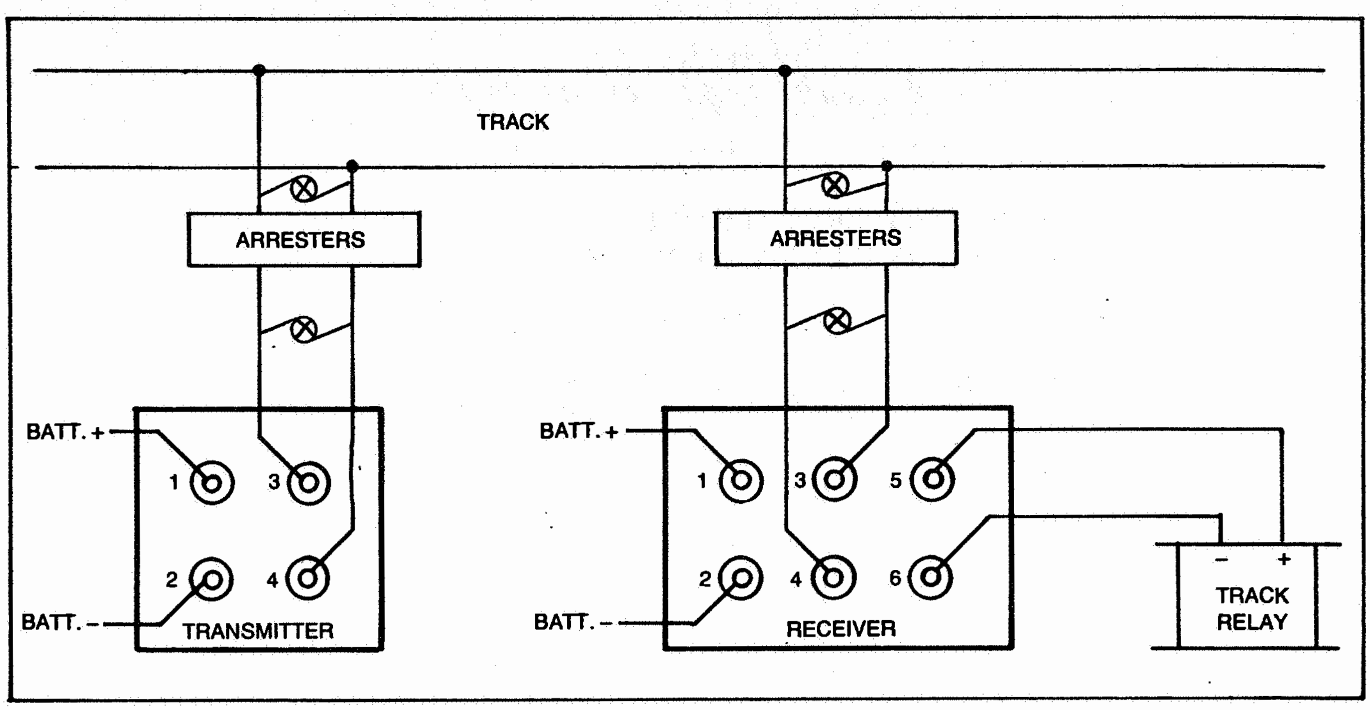


Figure 3-1. Typical Wire Connections for Transmitter and Receiver

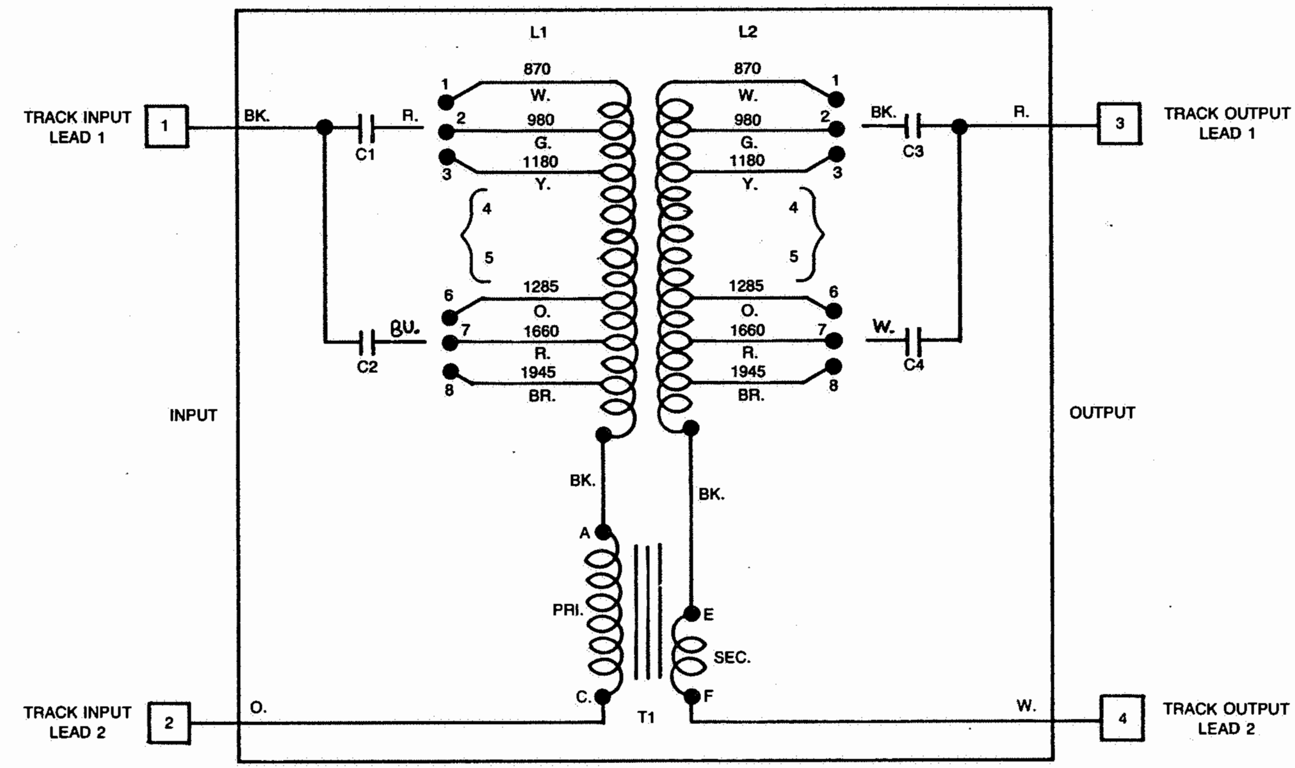
2. Connect the black and brown wires to one of the assigned frequencies as indicated on terminals one to eight.

3. Connect the white and blue wires only when one of the first three frequencies in each group located in Table 3-1 are assigned. When not assigned, these wires should be connected to the spare terminal 4.

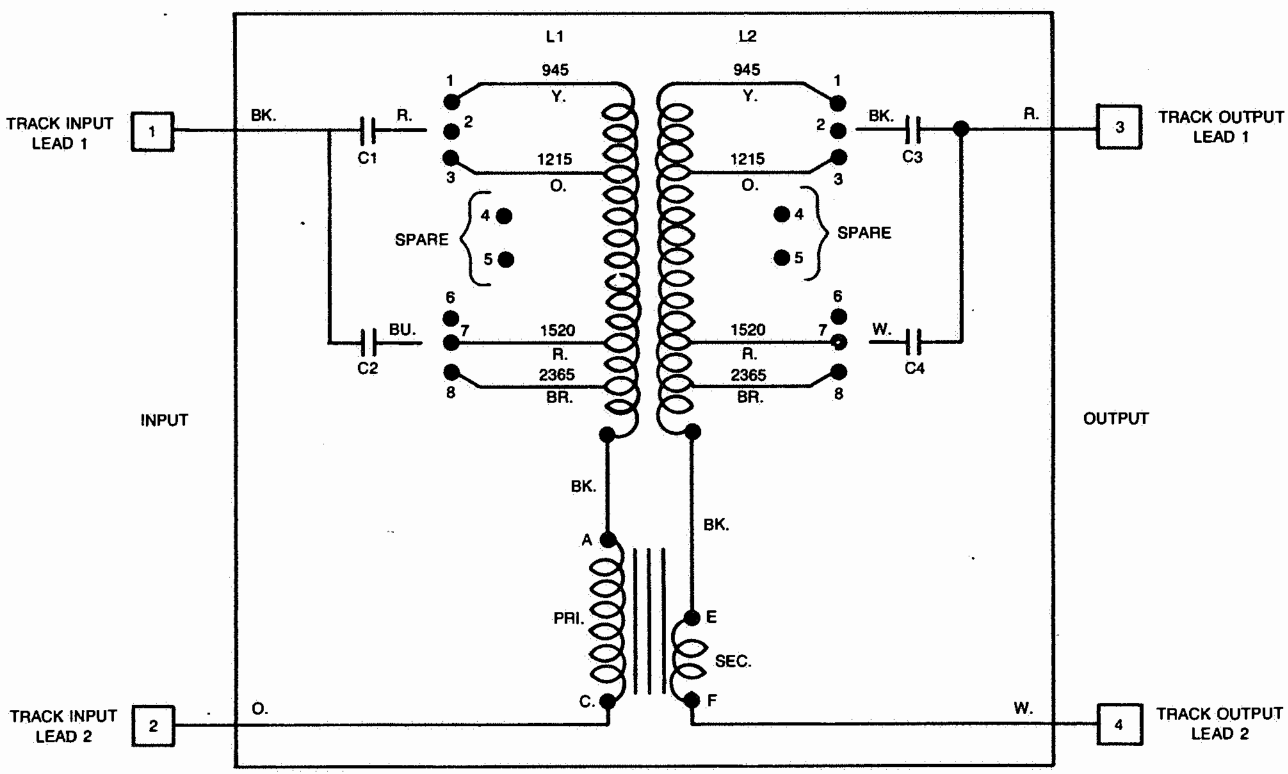
4. Reassemble the unit in its sheet metal cover.

Table 3-1. Coupling Unit Internal Terminal Board Connections

Frequency (Hz)				Connect Wire (Color) On Terminal			
Group 1	Group 2	Group 3	Group 4	Black to Term. #	Brown to Term. #	White to Term. #	Blue to Term. #
885	930	--	--	1	1	1	1
1050	1120	--	--	2	2	2	2
1330	1420	--	--	3	3	3	3
1860	2140	--	--	6	6	4	4
2540	2720	--	--	7	7	4	4
3360	3410	--	--	8	8	4	4
--	--	870	945	1	1	1	1
--	--	980	--	2	2	2	2
--	--	1180	1215	3	3	3	3
--	--	1285	--	6	6	4	4
--	--	1660	1520	7	7	4	4
--	--	1945	2365	8	8	4	4

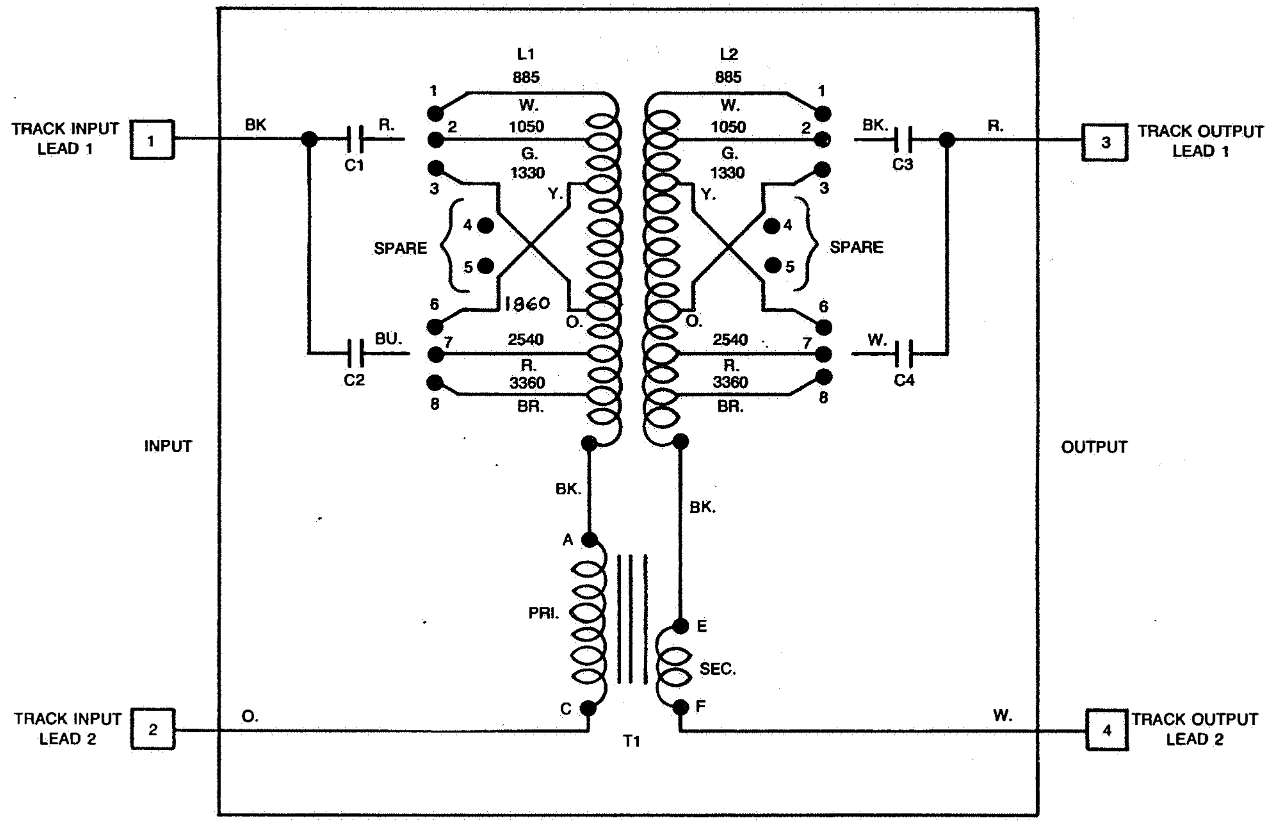


CIRCUIT DIAGRAM FOR BOARD #3 N451053-5803

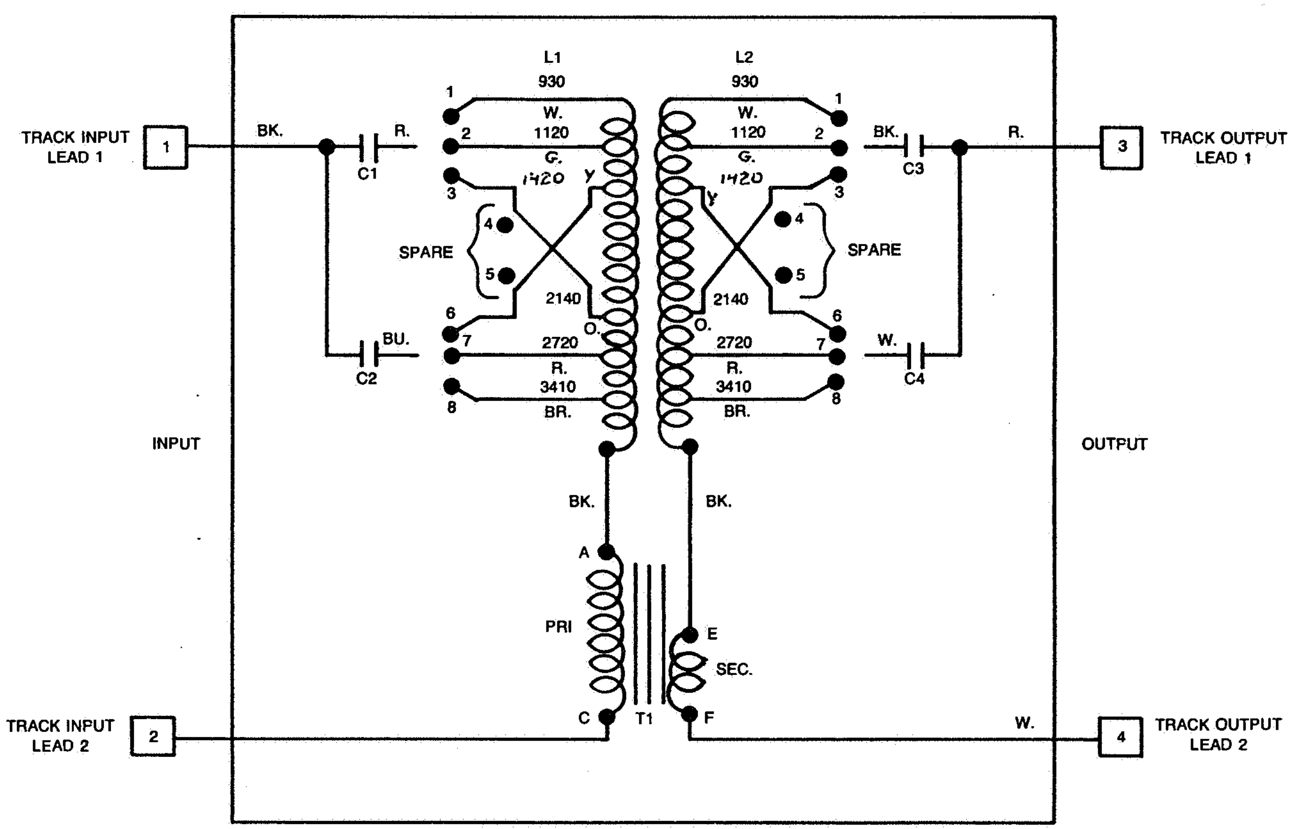


CIRCUIT DIAGRAM FOR BOARD #4 N451053-5804

Figure 3-2. Track Coupling Unit Internal Wiring Connections Groups 1 and 2 (N451052-1901 and -1902)



CIRCUIT DIAGRAM FOR BOARD #1 N451053-5801



CIRCUIT DIAGRAM FOR BOARD #2 N451053-5802

Figure 3-3. Track Coupling Unit Internal Wiring Connections Groups 3 and 4 (N451052-1903 and -1904)

After making the proper internal connections, connect the unit to the track as follows (see Figure 2-5):

1. Connect track leads from terminals 1 and 2 to the rails on the transmitter side of the insulated joints.

2. Connect track leads from terminals 3 and 4 to the rails on the receiver side of the insulated joints.

3.1.4 Blocking Reactor (See Figure 2-3)

Asc required by the application, connect the Blocking Reactor in series with one side of a circuit or track lead using terminals 1 and 2.

3.2 EQUIPMENT ADJUSTMENTS

NOTE

> Do not proceed with the following adjustments until all wiring connections have been completed.

Initial adjustments must be made as follows:

1. Using a voltmeter, check for correct output voltage on the dc supply that will be used at the transmitter and receiver (nominal 12 volts).

2. Connect dc power to all AFO-IIC equipment; make certain to observe proper polarity.

NOTE

> The equipment will not be damaged if dc power is applied with the wrong polarity, but the protective fuses will be blown and must be replaced before further operation.

3. Connect a dc voltmeter (minimum 10,000 ohms/volt sensitivity and a 0-10 volt range) across the relay terminals.

4. When power is applied, a dc voltage of at least 5.5 volts should be developed across the receiver relay terminals. If the voltage is not at least 5.5 volts, loosen the lock nut on the receiver's sensitivity adjustment and turn the shaft clockwise until the voltage is as specified. Then lightly tighten the lock nut.

NOTE

> If at least 5.5 volts cannot be obtained, check all connections on the transmitter, receiver, track coupling units, and reactors.

NOTE

The AFO-IIC receiver incorporates an electronic level detector in the relay driver circuit. The hysteresis of this circuit, when operated near its threshold, is relatively narrow and therefore quite sensitive to environmental changes. From a maintenance standpoint, it would be tedious to readjust the circuit every time a small change has taken place in the intervening period. Therefore, it is recommended that the AFO-IIC approach track circuit be initially adjusted for a shunting sensitivity in excess of .06 ohms. Typically, a value between .07 and .10 ohms is desirable.

5. Connect a 0.08 ohm resistance shunt across the rails at the receiver track connections. Use rail clamps to insure a good contact.

NOTES

In no case should the AFO-IIC Receiver be adjusted for a shunt of less than 0.06 ohm resistance. If a higher Resistance shunt is used, the overlap distance will be increased proportionately.

The following adjustment should be made when the ballast is in good condition (20 ohms or higher per one thousand feet). This should avoid any appreciable decrease in shunting sensitivity with any further improvement in ballast. Also, all batteries must be fully charged and all track equipment connected when the adjustment is made.

6. Loosen the receiver sensitivity adjustment lock nut and adjust the receiver sensitivity so that the relay just drops out with the shunt in place. Observe and record the voltmeter reading.

7. Tighten the sensitivity adjustment lock nut and check the voltmeter to see that such tightening has not changed the voltmeter reading. If necessary, loosen the nut, readjust the sensitivity and tighten the nut again.

8. Remove the track shunt. The relay should then pick up.

9. Observe and record the voltmeter reading.

10. Check that the circuit shunts with a 0.06 ohm shunt at the transmitter end of the circuit.

NOTES

If a transmitter or receiver is ever removed or replaced in service, the circuit must be readjusted according to the above procedure.

Multiple receivers are frequently used to provide several track circuits with one transmitter. The shunting of each receiver must be adjusted individually. Adjustment of one receiver will not appreciably affect the adjustment of another receiver.

10. After completing all adjustments, a check should be made throughout the AFO track circuit, end to end, to insure that the track relay will shunt down with a 0.06 ohm shunt anywhere within the limits of the track circuit (between the transmitter and all receivers.)

SECTION IV
FIELD MAINTENANCE

4.1 GENERAL

Repairs to AFO-IIC transmitters, receivers and related equipment should not be attempted in the field. A defective unit should be replaced with a properly working spare, and then repaired. Defective units may be returned to US&S for repair or replacement. A Returned Material Report (RMR) form may be obtained through any district sales office. Faulty units may be isolated either through direct substitution with spare units, or by taking input and output voltage measurements on the installed units. Substitution of complete units is recommended.

NOTE

> If an AFO-IIC Transmitter, Receiver or Receiver relay must be replaced, the associated track circuit must be readjusted as described in section 3.2.

4.2 REQUIRED TEST EQUIPMENT

A dc voltmeter is required for all types of AFO-IIC field maintenance. The voltmeter is used to check battery supply voltage. When a spare transmitter and receivers of the proper frequency are carried to the installation, no other test equipment is required. When spares are not available, a multimeter is required. The multimeter should have a 10,000 ohms per volt minimum input impedance, a 0-2.5 Vac RMS range, and a 0-50 Vdc range.

4.3 INSPECTION AND INITIAL CHECKS

The following inspections and checks may be performed in accordance with the customer's scheduled inspections of related field equipment:

1. Check the condition of the cases, terminals and wiring for impact damage, cracks, loose components, frayed insulation etc.

2. Check all lightning arresters for any clearly damaged or destroyed units. Use the multimeter to check the continuity of the intact arresters. A shorted arrester should be replaced.

3. Using a dc voltmeter, check the battery voltage for 9.5 to 16.2 volts. The voltage reading must be within this range for proper operation of the AFO equipment.

4. Shunt the track circuit and check the control relay voltage with a dc voltmeter. Compare it with the last recorded reading.

4.4 MAINTENANCE PROCEDURES

4.4.1 Equipment Substitution Method

Where a spare transmitter and receiver of the correct frequency are available, the following method may be used to determine the cause of failure or improper operation of an AFO track circuit installation.

a. Check the battery for a reading of 9.5 to 16.2 volts.

b. Substitute a spare transmitter for the original and check operation. If operation is not correct, go to step step c.

c. Substitute a spare receiver for the original, adjust per section 3.2 and check operation. If operation is now correct, reconnect the original transmitter and check operation again (both receiver and transmitter could be defective). Readjust the track circuit again per section 3.2.

d. If neither the battery, transmitter, or receiver are faulty, check the track bootleg connections and the AFO relay. A defective Track Coupling Unit may be a cause of the difficulty. Check all terminals used in the coupling unit to ensure proper connection. Refer to section 3.1.3 for coupling unit wire connections.

4.4.2 Voltage Measurement Method

Receiver and transmitter output voltages may be measured to determine the condition of these units, as follows:

a. Check the battery voltage for 9.5 to 16.2 volts.

b. Using the 10,000 ohms-per-volt dc voltmeter, measure the receiver output voltage at terminals #5 and #6 for a value equal to or higher than the pickup voltage of the AFO relay. If this voltage is at the pick-up voltage or above, the difficulty may be in the AFO relay or wiring between the unit and the relay.

c. If the voltmeter reading at terminals #5 and #6 shows low voltage, recheck the track circuit adjustment per section 3.2.

d. If the proper receiver output voltage is not obtained, disconnect the transmitter from the track circuit. Place a 2.0 ohm load across the transmitter output terminals and measure the transmitter output ac voltage. Since the signal is modulated, the reading should be taken with an oscilloscope. The output should be approximately 5.0 volts P-P during the "on" period of the modulation. If a VOM is used to read the output, then the voltage should be above 0.9 volt RMS. If the voltage is less than these values, the transmitter is faulty and should be replaced. If neither the transmitter or receiver is faulty, the problem may be in the track leads or connections, or in the rail bond connections.

SECTION V
SHOP MAINTENANCE

5.1 GENERAL

Because of the vital functions performed by the AFO-IIC equipment, shop maintenance should only be performed by properly equipped and trained personnel. Maintenance procedures in this section consist of separate verifications of the transmitter, receiver and track coupling units. The transmitter and receiver test procedures begin with the units fully assembled. The units are then disassembled during these procedures to access circuit board test points. When the AFO-IIC transmitter or receiver is disassembled, the maintainer should examine the circuit boards for the condition of the fuses, burned wires or components, loose or missing components, broken component leads and broken wires. Refer to Appendix A for wiring diagrams of these units. The circuit boards should also be checked for physical damage. Faulty units should be returned to US&S for repair and/or recalibration.

5.2 TRANSMITTER UNIT N451052-29XX

5.2.1 Detailed Circuit Description (See Figure 5-1)

The carrier frequency is determined by T1 and C1, typically adjustable via T1 over an approximate 20% variation in frequency. R4 in conjunction with the turns ratio in T1 is chosen for an approximate 110% feedback, a compromise between failure to oscillate and continued oscillation should D1 fail to open. The modulation frequency is fixed at one of six chosen rates and chiefly comprises IC1 acting as a Twin-Tee oscillator. The 8 volt P-P output is controlled by the Zener voltage of D1 (approximately 4 Vdc). This is intended to assure operation of D1 by incorporating it into the tank circuit of the carrier oscillator. Transistor Q2 acts as a collector-modulated mixer. The combined signal is buffered through Q3 and passes through R11 to have the low frequency components filtered out by C5. L1 and C5 are tuned to the carrier frequency and adjustable via L1 over a an approximate 20% frequency range. R11 is the gain adjusting resistor. The signal passing through C6 now appears as a conventional 100% amplitude modulated signal. IC2 is used primarily as a buffer stage into transistors Q4 and Q5 and receives feedback from their common emitter output. The feedback from the output allows the stage to operate class C, improving efficiency. C8 couples the signal into T2, which is used as a driver transformer to Q6 and Q7, the output transistors. Both Q6 and Q7 act as emitter followers to drive T3, the output transformer. D3 and D4, bias the bases of Q6 and Q7 slightly positive to avoid crossover distortion in the output. The output filter of C11 and L2 is tuned to the carrier frequency.

5.2.2 Required Test Equipment

Device	Specifications
Oscilloscope: (Tektronics 2215 or equivalent)	- Bandwidth: 50 MHz - Time base: .05 usec. to 0.5 sec./div. - Time base accuracy: ± 4% - Voltage accuracy: ± 4% - Sensitivity: 2 mV/div.
Frequency Counter: (Hewlett Packard 5307A or equivalent)	- Freq. range: 5 Hz to 2 MHz - CPM Mode: 50 to 100 counts/ minute - Input impedance: 1.0 megohm - Input sensitivity (min): 10 mV RMS
Power Supply: (HP 6267B or equivalent)	- Voltage range: 0 to 40 Vdc - Current range: 0 to 10 amps - Ripple at any given output within above range: less than 10 mV P-P
*Resistor: (Dale RH-10 or equivalent)	- 2.0 Ohm, 10 Watt, ± 1% tolerance (US&S J735519-0624)

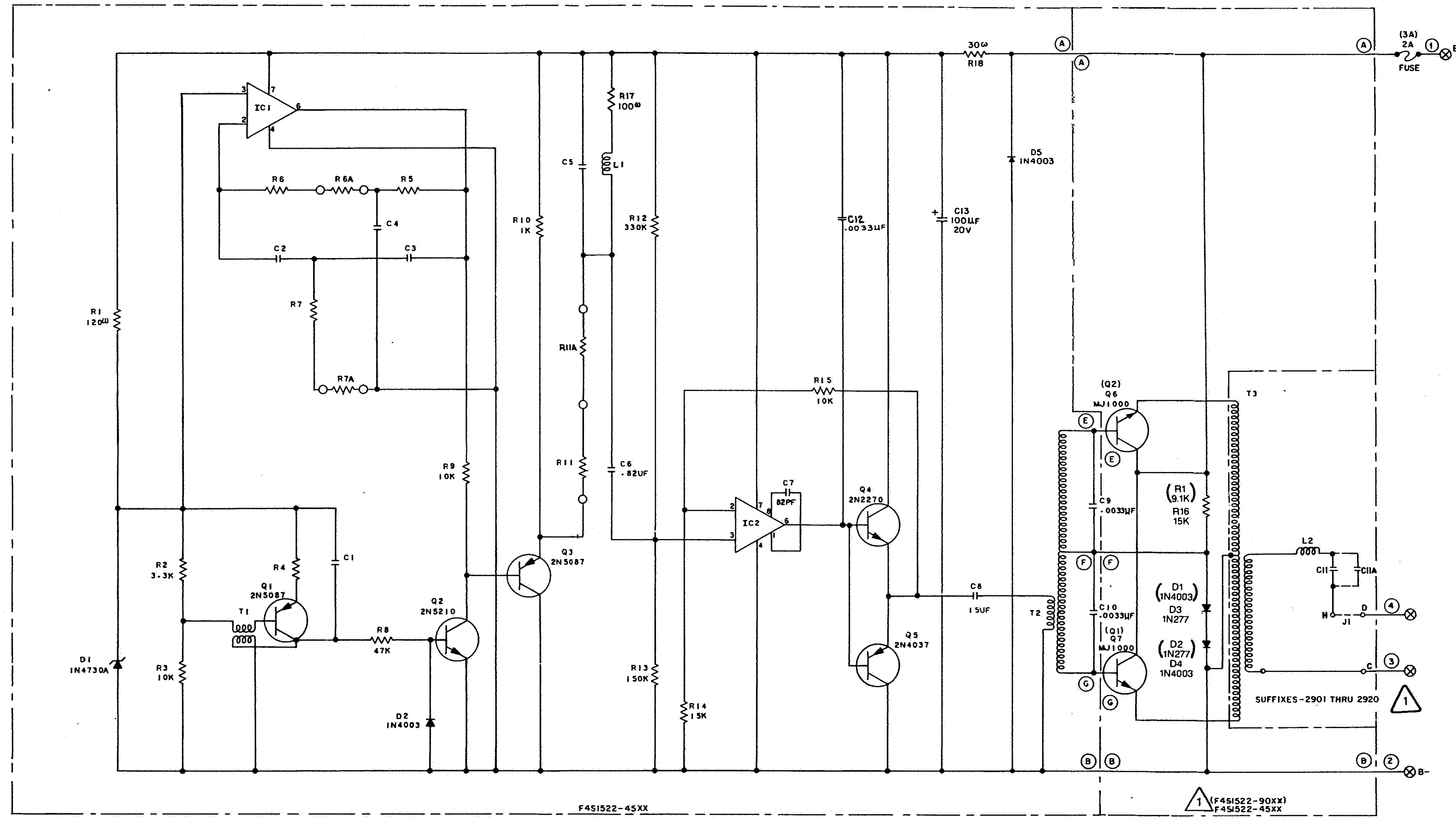
5.2.3 Test Set-Up

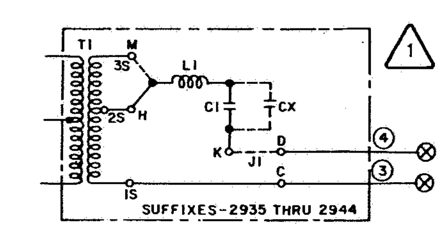
Figure 5-2 shows the test set-up for the AFO-IIC Transmitter. Before turning on the power supply, make certain the voltage adjustment is set to minimum. Then turn power supply on and adjust to 12 ± 0.1 Vdc.

5.2.4 Procedure Comments

The AFO-IIC transmitter is set by adjusting the peak-to-peak output voltage to relatively narrow limits across a fixed 2.0 ohm load. This allows the voltage spread on various units to be small near the output stage of the transmitter. This spread, however, will become increasingly large (due to compiling of variations) toward the front or carrier (modulator) end of the transmitter. DC voltage levels of all measured ac signals must fall within ± 10% of those levels shown in the waveform of the test point in question unless otherwise noted.

Certain tests are verified with oscilloscope waveform diagrams (oscillograms), which represent the typical waveforms and voltage levels present at various points in the AFO-IIC Transmitter circuitry. The oscillograms are shown in Figure 5-5. Figures 5-3 and 5-4 show the physical and schematic locations, respectively, of the receiver test points. The oscillograms represent typical





1. TRANSMITTERS WITH SUFFIXES -2901 THRU -2920 (NOW -2965 THRU -2987) REQUIRE A SINGLE PCB (F451522-45XX). THE UNBRACKETED NOMENCLATURE IS VALID.

SPECIAL HIGH POWER APPLICATION TRANSMITTERS WITH SUFFIXES -2935 THRU -2944 REQUIRE TWO PCB'S (F451522-45XX AND F451522-90XX). THE BRACKETED NOMENCLATURE IS VALID: THE UNBRACKETED COMPONENTS ARE DELETED FROM PCB F451522-45XX. THESE BOARDS ARE NOT COVERED IN THIS MANUAL.

THE SECONDARY CIRCUIT OF THE OUTPUT TRANSFORMER T3 HAS ONE (1) EXTRA TAP FOR SUFFIXES -2935 THRU -2944 AND IS SHOWN SEPARATELY.

WARNING

THIS IS A VITAL SAFETY CIRCUIT. ANY CIRCUIT CHANGE OR SUBSTITUTION CAN COMPROMISE THE SAFE PERFORMANCE OF THIS CIRCUIT. ALL COMPONENTS SHALL BE REPLACED ONLY BY THOSE SPECIFIED ON THE US&S BILL OF MATERIAL.

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Figure 5-1. AFO-IIC Transmitter Unit Schematic Diagram

waveforms and voltages generated in the AFO-IIC transmitter. Small variations in the actual waveforms and voltages may occur with the particular unit under test. These are acceptable for test results.

NOTE

The oscilloscope horizontal sweep rate settings required to produce the represented waveforms will vary, depending on the selected frequency and code rate of the AFO-II unit under test. Except where noted, the oscilloscope time base is the same for all waveform diagrams. Battery voltage 12 ±.1 Vdc. The oscilloscope probe input impedance is 10 megohms.

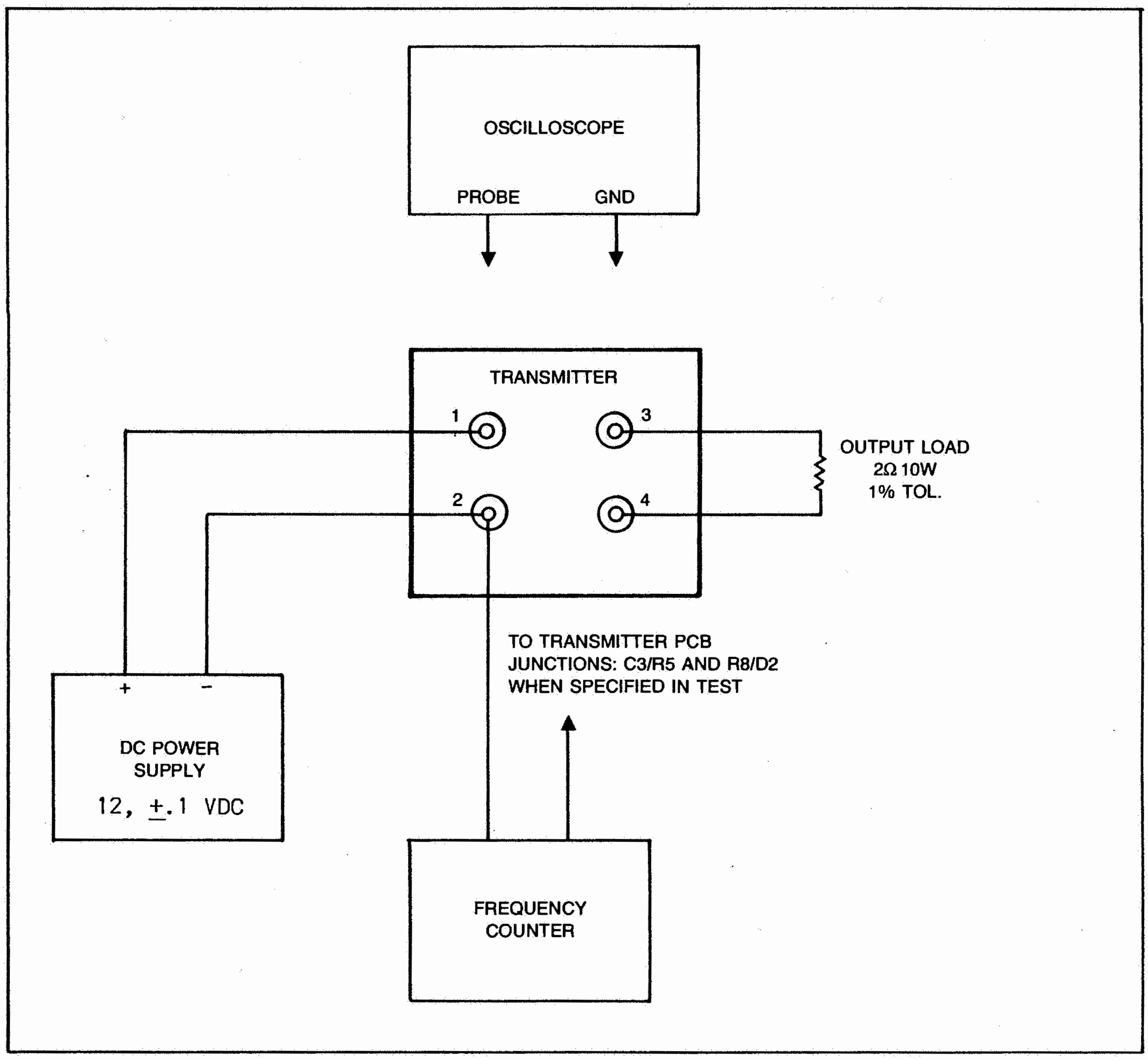


Figure 5-2. Transmitter Test Set-Up

Connection Point Numbers: 1 - 7

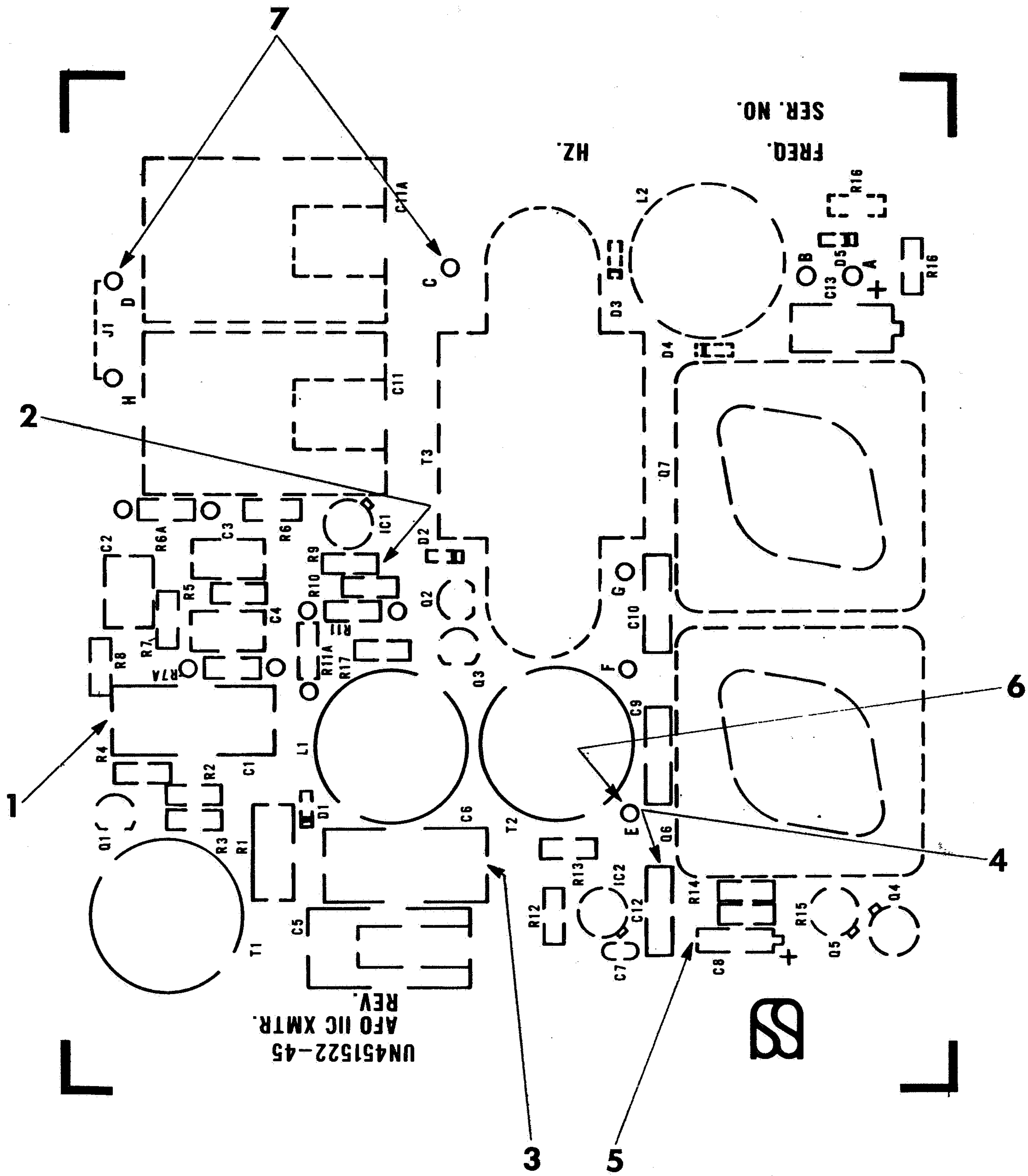


Figure 5-3. Physical Locations of Transmitter Test Points

Connection Point Numbers: 1 - 7

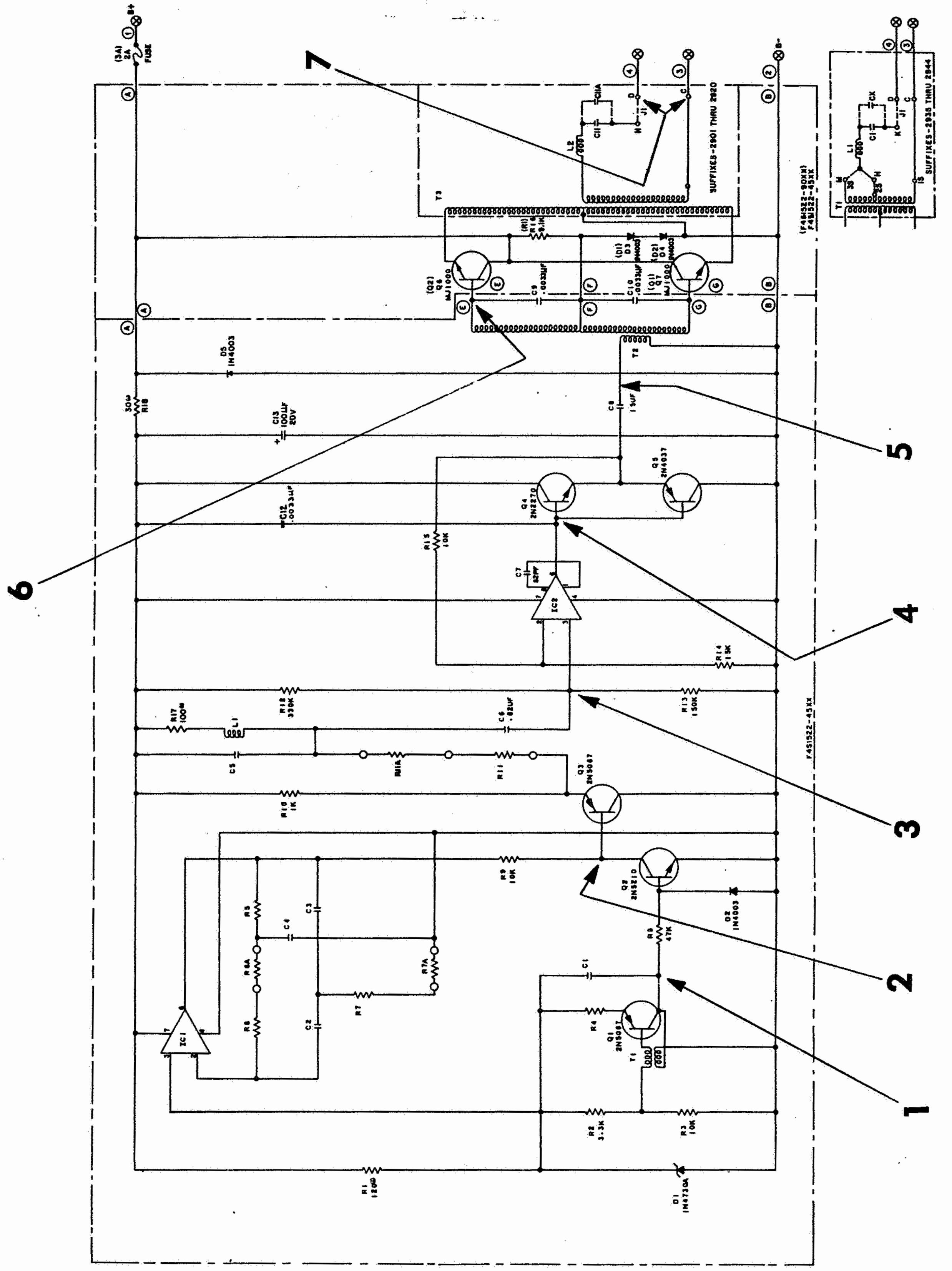


Figure 5-4. Schematic Locations of Transmitter Test Points

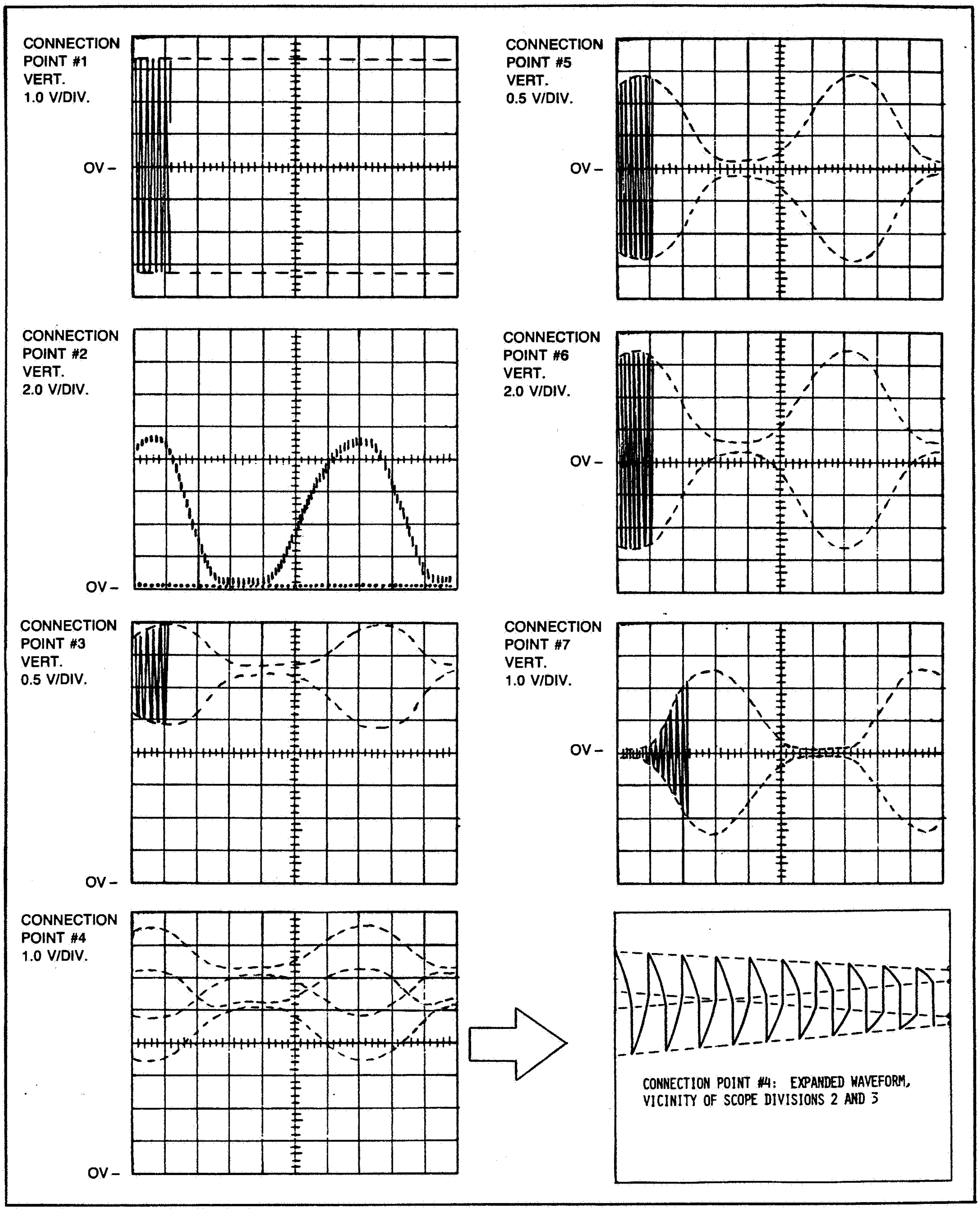


Figure 5-5. Transmitter Test Oscillograms

5.2.5 Procedure Steps

Operation	Verification
1. Connect the frequency counter to the junction of C3 and R5, and AAR terminal 2 (-dc).	1. Frequency should be within 1% of modulation rate. Check value against Table 2-1. If modulation frequency exceeds 1% limit, go to section 5.2.6.
2. Connect the frequency counter to the junction of R8 and D2, and AAR terminal 2.	2. Carrier frequency should be within 0.4% of its specified frequency. If carrier frequency exceeds the 0.4% limit, go to section 5.2.6.

NOTE

For a quick check, go to step 6 and verify that the level of the output waveform is correct. If not, continue with step 3.

Operation	Verification
3. Connect oscilloscope to Connection Point 2 shown in Figures 5-3 and 5-4.	3. Amplitude of modulated carrier signal should be 8.8 ± 0.8 volts P-P. See Fig. 5-5, oscillogram #2 for general shape and dc level of waveform. If P-P and dc values are incorrect, go to section 5.2.6.
4. Connect oscilloscope to connection Point 3 shown in Figures 5-3 and 5-4.	4. Amplitude of modulated carrier signal should be 1.55 ± 0.2 volts P-P. See Fig. 5-5, oscillogram #3 for general shape and dc level of waveform. If P-P and dc values are incorrect, go to section 5.2.6.
5. Connect oscilloscope to Connection Point 5 shown in Figures 5-3 and 5-4.	5. Amplitude of modulated carrier signal should be 2.8 ± 0.3 volts P-P. See Fig. 5-5, oscillogram #5 for general shape and dc level of waveform. If P-P and dc values are incorrect, refer to section 5.2.6.
6. Connect oscilloscope to Connection Point 7 shown in Figures 5-3 and 5-4.	5. Amplitude of modulated carrier signal should be 5.0 ± 0.4 volts P-P. See Fig. 5-5, oscillogram #7 for general shape and dc level of waveform. If P-P and dc values are incorrect, refer to section 5.2.6.

5.2.6 Procedure Follow-Up

A failure of any step in the above procedure can be caused by a variety of circuit or component defects. Failure to meet the frequency tolerance requirement in steps 1 and 2 may be due to a long-term drift of associated components in the respective oscillator circuits.

When an AFO-IIC transmitter fails the verification test, it should be returned to US&S for repair and recalibration. This is particularly true if any of the following components are defective:

Inductors L1, L2	Integrated Circuit IC1
Transformer T1	Zener Diode D1
Capacitors C1, C2, C3, C4, C5, C11, C11A	Resistors R2, R3, R4, R5, R6, R6A R7, R7A, R8, R9, R11, R11A, R17
Transistor Q1	

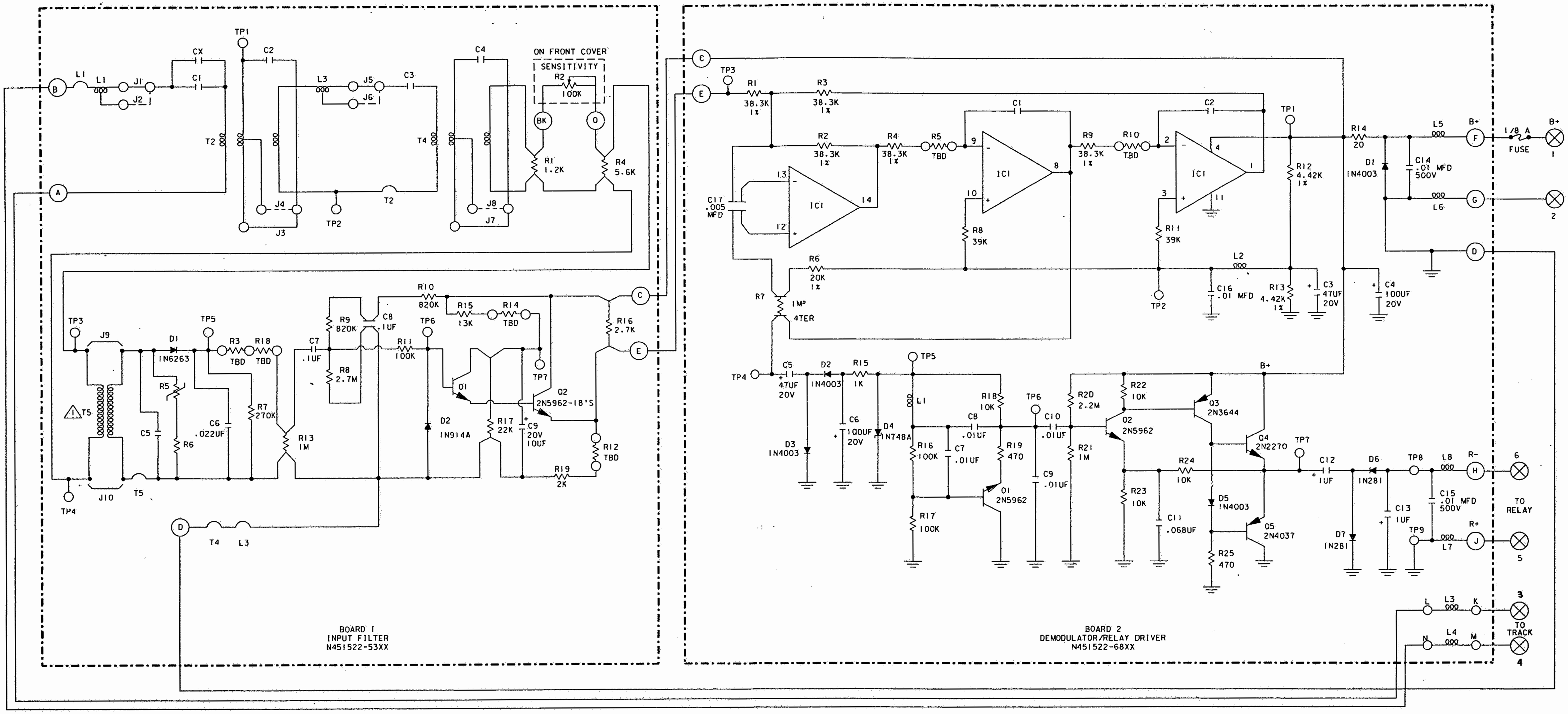
These components either directly or indirectly affect the tuning of the carrier and modulation oscillators and gain adjustment.

5.3 RECEIVER UNIT N451052-31XX TEST PROCEDURES

5.3.1 Detailed Circuit Descriptions (See Figure 5-6)

Input Filter Board N451522-53XX - The track signal is applied to this board through a low impedance, series-tuned filter comprised of C1 and L1. Along with the above components, C2, C3, C4, T2, L3, and T4 make-up a narrow band-pass filter. The filter passes the amplified carrier with its modulation side bands, but rejects noise and adjacent channel signals. The output of the filter is terminated by network R1, R2 and R4, which imposes (within limits) a constant load to the filter. R2 provides a level adjustment to compensate for variations from filter to filter. Step-up transformer T5 sufficiently increases the signal level to enable detector D1 to operate in its linear region at low temperatures. Network R3, R13 is used for factory adjustment of the receiver for minimum sensitivity. The R8, R9, R10, C7, and C8 circuit shifts the dc operating level to about half the battery supply voltage. Q1 and Q2 make up an emitter-follower circuit which transforms the impedance to a sufficient output level. To prevent potential electrical interference, which could result in energizing the relay, the Darlington's circuit (Q1 and Q2) acts as a signal limiter circuit whose output is limited to approximately 1.5 Vpp. Extraneous electrical impulses are limited to the 1.5 Vpp therefore having no effect on the demodulator circuit (IC1) on the Demodulator/Relay Driver board.

Demodulator/Relay Driver Board N451522-68XX - The output of the Input Filter board is resistively-coupled to the active band-pass filter, consisting of IC1 and associated circuitry. The filter amplifies the modulation frequency but rejects noise and adjacent channel signals. C5, C6, D2 and D3 produce a negative dc from the output signal to operate a low-power oscillator, which acts as a



NOTE:
⊗ = AAR TERMINAL

WARNING

THIS IS A VITAL SAFETY CIRCUIT. ANY CIRCUIT CHANGE OR SUBSTITUTION CAN COMPROMISE THE SAFE PERFORMANCE OF THIS CIRCUIT. ALL COMPONENTS SHALL BE REPLACED ONLY BY THOSE SPECIFIED ON THE US&S BILL OF MATERIAL.

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Figure 5-6. AFO-IIC Receiver Unit Schematic Diagram

level detector. The 22 KHz output signal of the oscillator is amplified by Q2, Q3, Q4 and Q5. The signal is then rectified and filtered by C12, C13, D6 and D7 to produce a negative dc voltage sufficient to energize the AFO relay. To guard against false pickup of the track relay due to radio interference, inductive beads L2-L8 were inserted in line with the leads from the receiver box. Capacitors C14 - C17 are used for additional decoupling. D1 provides reverse battery protection, and C4 provides power surge protection at the battery connection. Network R12, R13, provides a reference voltage for IC1 while C3 further dampens any noise riding the battery line.

5.3.2 Required Test Equipment

Device	Specifications
Oscilloscope: (Tektronics 2215 or equivalent)	- Bandwidth: 50 MHz - Time base: .05 usec. to .5 sec./div. - Time base accuracy: ± 4% - Voltage accuracy: ± 4% - Sensitivity: 2 mV/div.
Frequency Counter: (HP 5307A or equivalent)	- Freq. range: 5 Hz to 2 MHz - CPM Mode: 50 to 100 counts/minute - Input impedance: 1.0 megohm - Input sensitivity (min): 10 mV RMS
Power Supply: (HP 6267B or equivalent)	- Voltage range: 0 to 40 Vdc - Current range: 0 to 10 amps - Ripple at any given output within above range: less than 10 mV P-P
DC Voltmeter: (Simpson 260 or equivalent)	- Voltage range: 0 to 5000 V - Input resistance: 20,000 ohms/Vdc, 5,000 ohms/Vac - Accuracy: ± 2% - Ohmmeter resistance range: 0 to 20 megohms, 3 ranges - Ohmmeter accuracy: ± 2% F.S. (dc), 3% F.S. (ac)
Function Generator: (Wavetek 146 or equivalent)	- Internal AM capability - Frequency range: .0005 Hz to 10 Mhz - Output impedance: 50 ohms - Output voltage: 10 volts P-P into 50 ohm load - Sine distortion: Less than 0.5% (10 Hz to 100 Khz)
Relay:	- US&S PN-150B (N322500-901) PN-150BH (N322511-006)

Audio Power Amplifier: (MacIntosh Model MC2100 or equivalent)	- Power output: 20.5 volts RMS across 4 ohm load - Output impedance: 4 ohms - Rated power band: 20 to 20,000 Hz - Total harmonic distortion: Less than 0.25%
Resistors:	- 7.5 Ohm, 1 Watt, non-inductive - 1.3 Ohm, 1 Watt, non-inductive
*(Dale RH-10 or equivalent)	- 2.0 Ohm, 10 Watt, ± 1% tolerance
*(Dale RS-5 or equivalent)	- 1.0 Ohm, 5 Watt, ± 1% tolerance
*Potentiometer:	- 1K Ohm

*Required only for test set-up with matched transmitter and receiver.

5.3.3 Test Set-Ups

An AFO-IIC Receiver unit under test requires (a) an input signal equivalent to the signal supplied by the transmitter unit at the field installation, and (b) that this signal have the proper impedance. This may be done with the matching AFO-IIC Transmitter or a function generator.

Figure 5-7 shows the equipment set-up for the matched transmitter and receiver units. This method of checking receiver sensitivity in this manner is not very accurate. In general, the transmitter is not an ideal source due to the makeup of the output stage. To avoid crossover distortion, the bases of the transmitter output stage consisting of Q6 and Q7 are biased slightly positive by means of

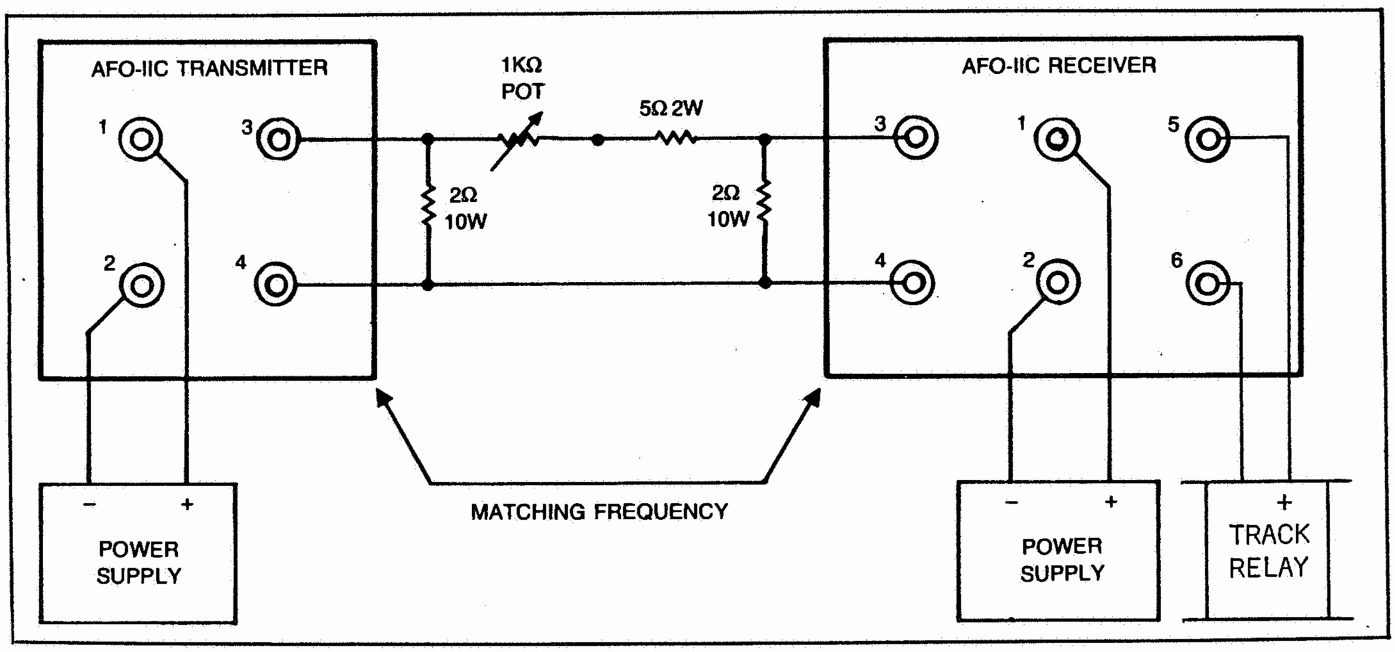

Figure 5-7. Receiver Test Set-Up Using Matched Transmitter and Receiver

diodes D3 and D4 (refer to section 5.2.1 for transmitter circuit description). As a result, the transmitter output signal is overmodulated by an amount that can vary from one unit to the next, and depends on the forward characteristics of the two diodes in question. In some cases, therefore, the transmitter would require more signal level during the "on" part of the period in order to provide the receiver with the same energy level. This "Go/No-Go" method of testing of the receiver can result in its sensitivity having a relatively wide range of 2.7 and 4.3 millivolts RMS as measured with a true RMS voltmeter.

The 1K ohm potentiometer in this set-up must be adjusted so that the signal at scope test point 11 (see page 5-19/20) is at 0.29 $\pm$ 0.03 volts P-P. To accomplish this, change the oscilloscope's vertical deflection adjustment to 0.1 V/div. ac. The receiver input level at this point in time should not exceed 4.3 millivolts RMS, as measured with a true RMS voltmeter.

Figure 5-8 shows the receiver unit test set-up with a function generator and audio power amplifier. The 7.5 and 1.3 ohm resistors must be non-inductive. The carrier and modulation frequencies developed on the function generator must be set according to those of the receiver under test. The index of modulation must be 95% or better, as measured with an oscilloscope across terminals 3 and 4 of the receiver. On the audio power amplifier, use only the lowest output impedance tap, preferably 2.0 or 4.0 ohm. Leave power off and the receiver disconnected until specified in the test procedure. When turning on power, set the power supply to its minimum voltage, then adjust to 12 $\pm$ 0.1 Vdc.

5.3.4 Procedure Comments

The following procedure is based on the test set-up shown in Figure 5-8. Certain tests are verified with oscilloscope waveform diagrams (oscillograms), which represent the typical waveforms and voltage levels present at various points in the AFO-IIC Receiver circuitry. The oscillograms are shown in Figure 5-11. Figures 5-9 and 5-10 show the physical and schematic locations, respectively, of the receiver test points. The oscillograms represent typical waveforms and voltages generated in the AFO-IIC receiver. Small variations in the actual waveforms and voltages may occur with the particular unit under test. These are acceptable for test results.

NOTE

> The oscilloscope horizontal sweep rate settings required to produce the represented waveforms will vary, depending on the selected frequency and code rate of the AFO-II unit under test. Except where noted, the oscilloscope time base is the same for all waveform diagrams. Battery voltage 12 $\pm$.1 Vdc. The oscilloscope probe input impedance is 10 megohms. The receiver input signal is approximately twice the indicated input sensitivity (6 $\pm$ 0.3 millivolts RMS).

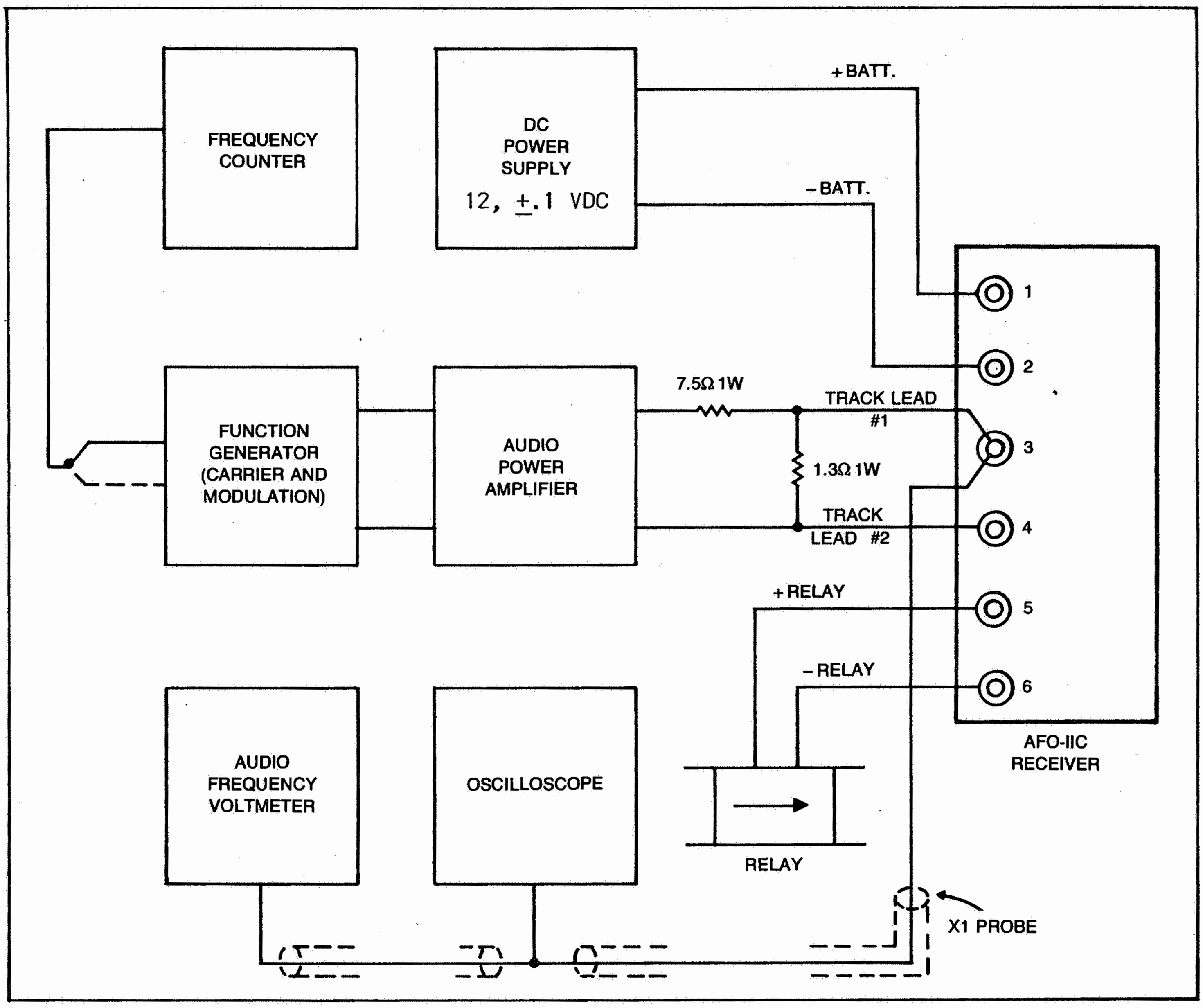

Figure 5-8. Receiver Test Set-Up Using Function Generator and Audio Amplifier

Connection Point Numbers: 8 - 17

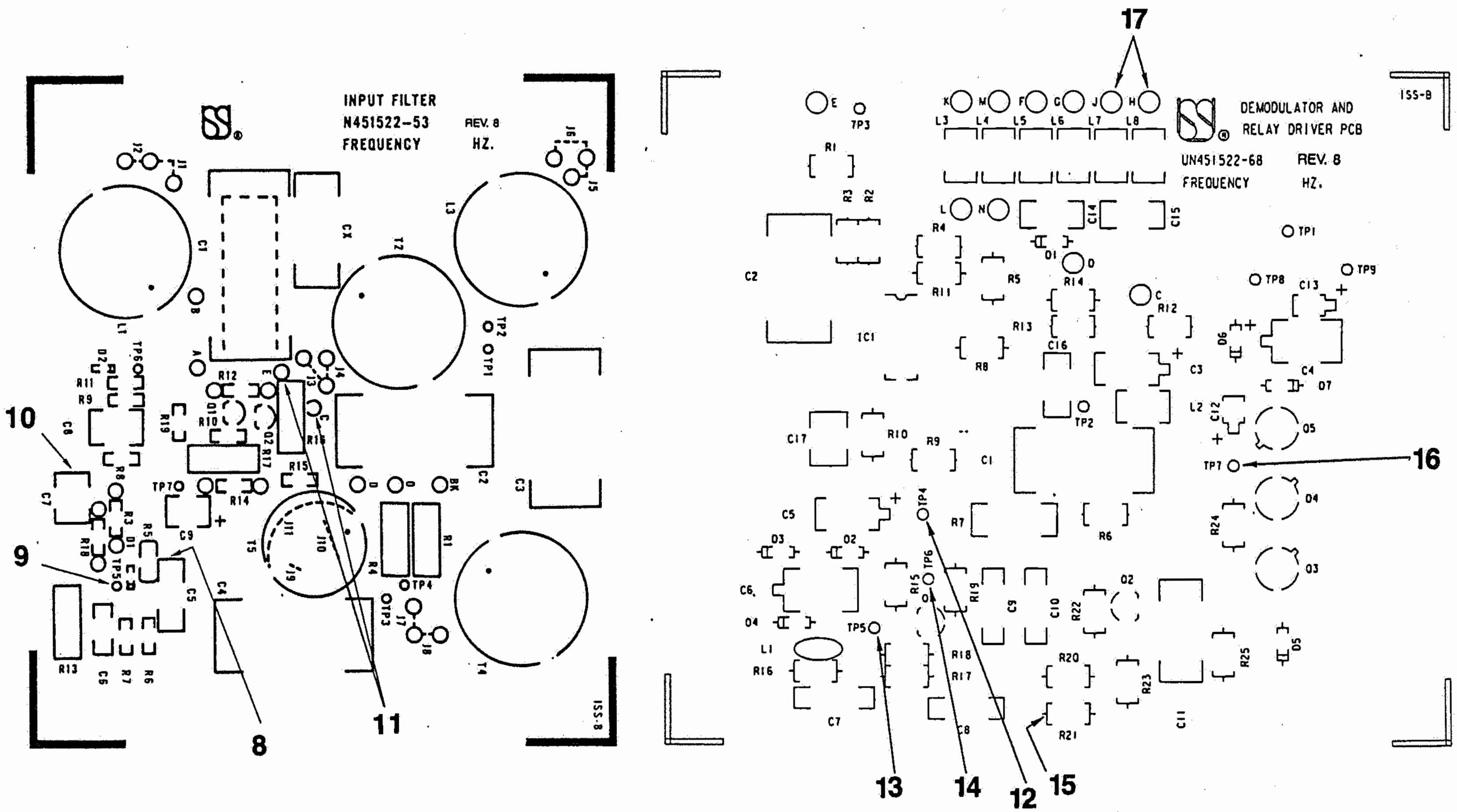

Figure 5-9. Physical Locations of Receiver Test Points

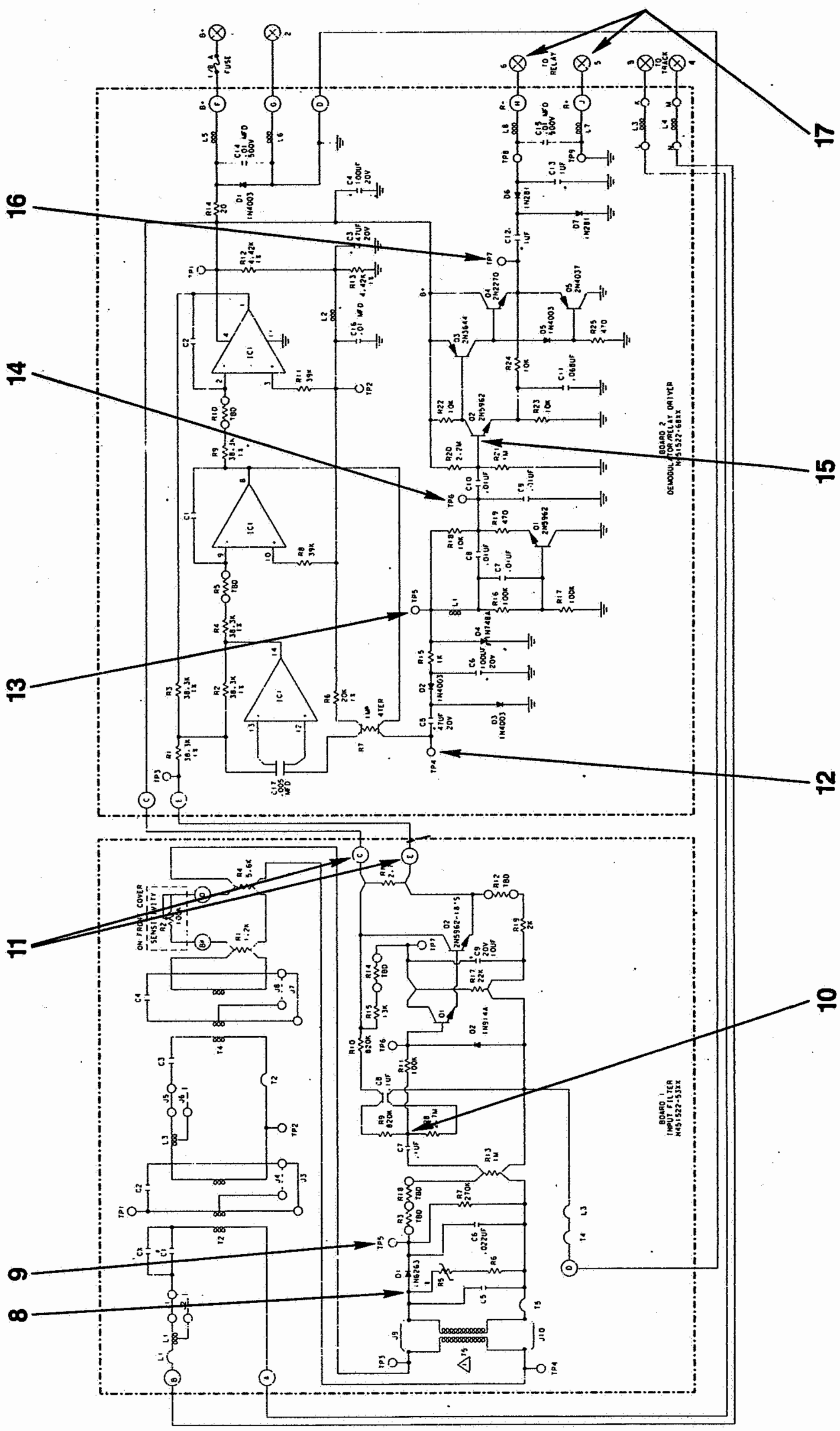

Figure 5-10. Schematic Locations of Receiver Test Points

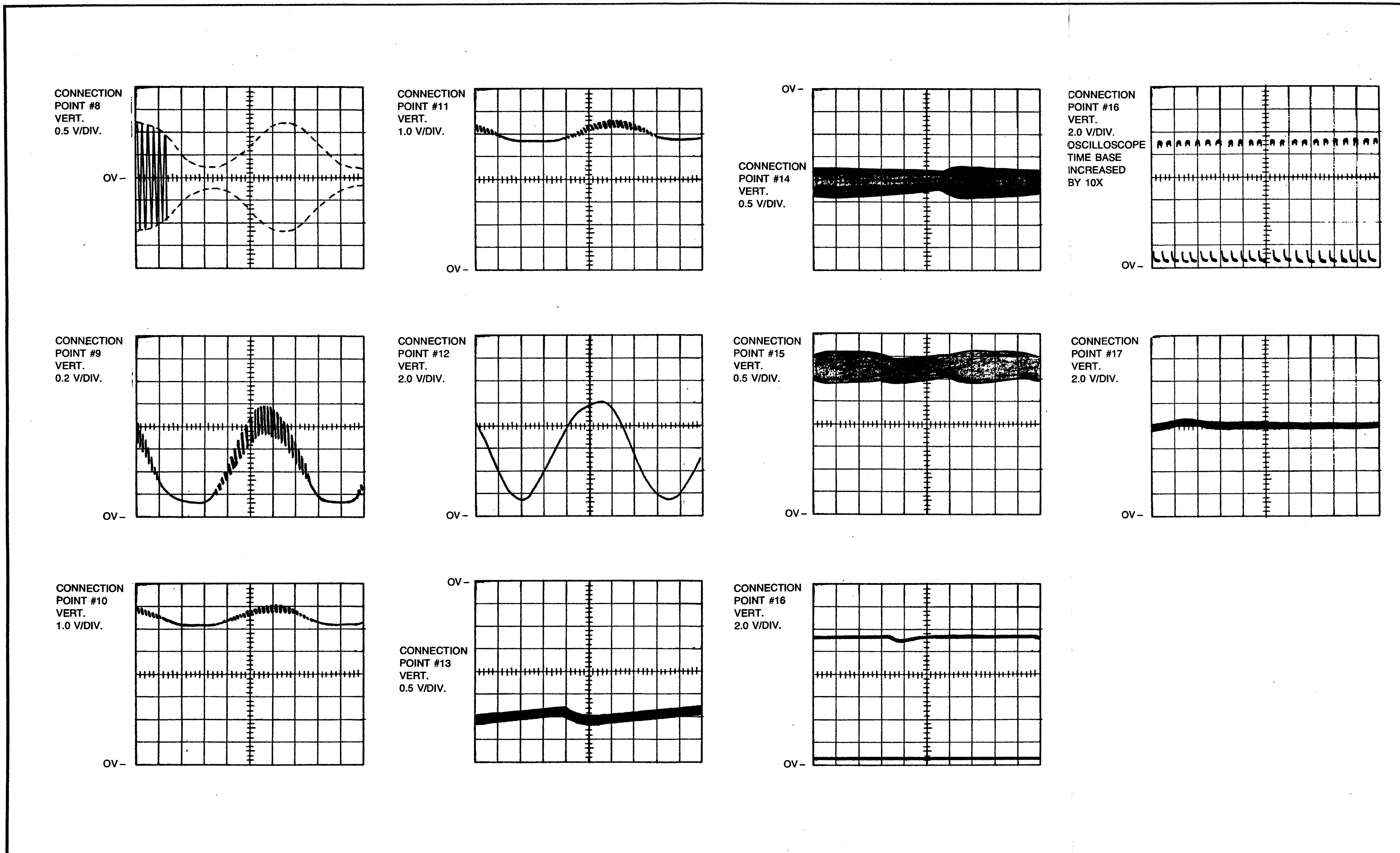

Figure 5-11. Receiver Test Oscillograms

5.3.5 Procedure Steps

Operation	Verification
1. Loosen the receiver sensitivity adjustment lock nut and adjust the potentiometer for maximum sensitivity.	1. The ohmmeter reading (between the black and orange wires of the sensitivity potentiometer R2) should be 0 ohms.
2. Set the carrier function generator for continuous output at the assigned carrier frequency ± 0.2%, and adjust the power amplifier output level to 3.0 millivolts RMS.	2. --
3. Turn on the amplitude modulation, adjust to the assigned modulation frequency ± 0.5%, and adjust amplifier output level to 3.0 ± 0.3 mV RMS.	3. --
4. Connect oscilloscope across the receiver input terminals. (#3 and #4).	4. The scope should show the index of modulation adjusted to at least 95% or better, but not exceeding 100%.
5. Connect a high impedance input probe of the oscillosope to oscilloscope Connection Point 9 shown in Figures 5-9 and 5-10 (TP5 on board 1).	5. Amplitude of signal should be 0.26 V P-P or higher. See Figure 5-11, oscillogram #9, for general shape dc of waveform. If P-P value is incorrect, go to section 5.3.6.
6. Connect a high impedance input probe of the oscillosope to oscilloscope Connection Point 11 shown in Figures 5-9 and 5-10 (turret lug "E").	6. Amplitude of signal should be 0.29 ± .03 V P-P. See Figure 5-11 oscillogram 11 for general shape and dc level of waveform. If P-P value is incorrect, go to section 5.3.6

NOTE

DC voltages of all the measured ac signals must fall within ± 10% of those levels shown in the test point oscillogram in question, unless otherwise noted.

Operation	Verification
7. Connect oscilloscope to Connection Point 12 shown in Figures 5-9 and 5-10 (TP4 on) board 2).	7. Amplitude of signal should be 4.9 ± .07 V P-P. See Figure 5-11, oscillogram #12 for general shape and dc level of waveform. If P-P value is incorrect, go to section 5.3.6

Operation	Verification
8. Connect oscilloscope to Connection Point 14 shown in Figures 5-9 and 5-10 (TP6 on board 2).	8. Average amplitude of 22 Khz signal should be 0.55 ± 0.1 V P-P. DC level should be -2.0 ± 0.3 Vdc. See Figure 5-11, oscillogram #14 for general shape and dc level of waveform. If P-P value is incorrect, go to section 5.3.6.
9. Connect oscilloscope to Connection Point 16 shown in Figures 5-9 and 5-10 (TP7 on board 2).	9. Amplitude of 22 KHz signal should be 10.4 ± 1.0 V P-P. See Figure 5-11 oscillogram 16 for general shape and dc level of waveform. If P-P value is incorrect, go to section 5.3.6
10. Connect a dc voltmeter across AAR terminals 6 (R-) and 5 (R+) (see Figure 5-10).	10. The receiver relay should be energized and the dc voltage falls between 5.5 and 8.0 Vdc.

5.3.6 Procedure Follow-Up

Failure of any step from 5 through 10 can indicate a number of circuit or component defects. If the receiver does not satisfy step 6, steps 1 through 5 should be rechecked. If the step 5 result does not meet the 0.03 volts P-P tolerance, but shows 0.25 volts P-P instead, return to step 3 and readjust the power amplifier output level to 3.3 millivolts RMS. This is the upper allowable limit of the receiver's input level. Then recheck step 6. A shift in the carrier and or modulation frequency equal to their allowable tolerances could affect the signal level in step 6.

When an AFO-IIC receiver fails the verification test, it should be returned to US&S for repair and recalibration. This is particularly true if any of the following components are defective:

<u>Input Filter Board</u>

Inductors L1, L3
Transformers T2, T4, T5
Capacitors C1, C2, C3, C4, C5, CX
Resistors R3, R13

<u>Demodulator/Relay Driver Board</u>

Integrated circuit IC1
Capacitors C1, C2
Resistors R4, R5, R6, R7, R9, R10

These components either directly or indirectly affect the tuning of the narrow band-pass filter, demodulator circuit and gain adjustment.

5.4 TRACK COUPLING UNIT

5.4.1 Required Test Equipment

Device	Specifications
Frequency Counter: (HP 5307A or equivalent)	- Freq. range: 5 Hz to 2 MHz - CPM Mode: 50 to 100 counts/minute - Input impedance: 1.0 megohm - Input sensitivity (min): 10 mV RMS
Function Generator: (Wavetek 146 or equivalent)	- Internal AM capability - Frequency range: .0005 Hz to 10 Mhz - Output impedance: 50 ohms - Output voltage: 10 volts P-P into 50 ohm load - Sine distortion: Less than 0.5% (10 Hz to 100 Khz)
Analog Voltmeter: (HP 3400A or equivalent)	- 10 Hz to 10 Mhz true RMS voltmeter - Voltage range: 1 mV to 300 V F.S., 12 ranges - DB range: -72 to +452 dBm - Input impedance: 10 megohms
Audio Power Amplifier: (MacIntosh Model MC2100 or equivalent)	- Power output: 20.5 V RMS across 4 ohm load - Output impedance: 4 ohms - Rated power band: 20 to 20,000 Hz - Total harmonic distortion: Less than 0.25%
*Resistor: (Dale RS-5 or equivalent)	- 1.0 Ohm, 5 Watt, ± 1% tolerance (US&S J587796)

5.4.2 Test Set-Up

The test equipment set up for the track coupling unit is shown in Figure 5-12. The signal generator should be adjusted to the frequency of the coupling unit under test. Refer to Table 3-1 and Figures 3-2 and 3-3 for frequency data.

5.4.3 Test Procedure Comments

The test procedure for the Track Coupling unit consists of a measurement of the output level across output terminals 3 and 4. A function generator and audio power amplifier are used to simulate the track signal. Adjustments of this input are included in the test to allow a certain margin of error in the tuning of the unit.

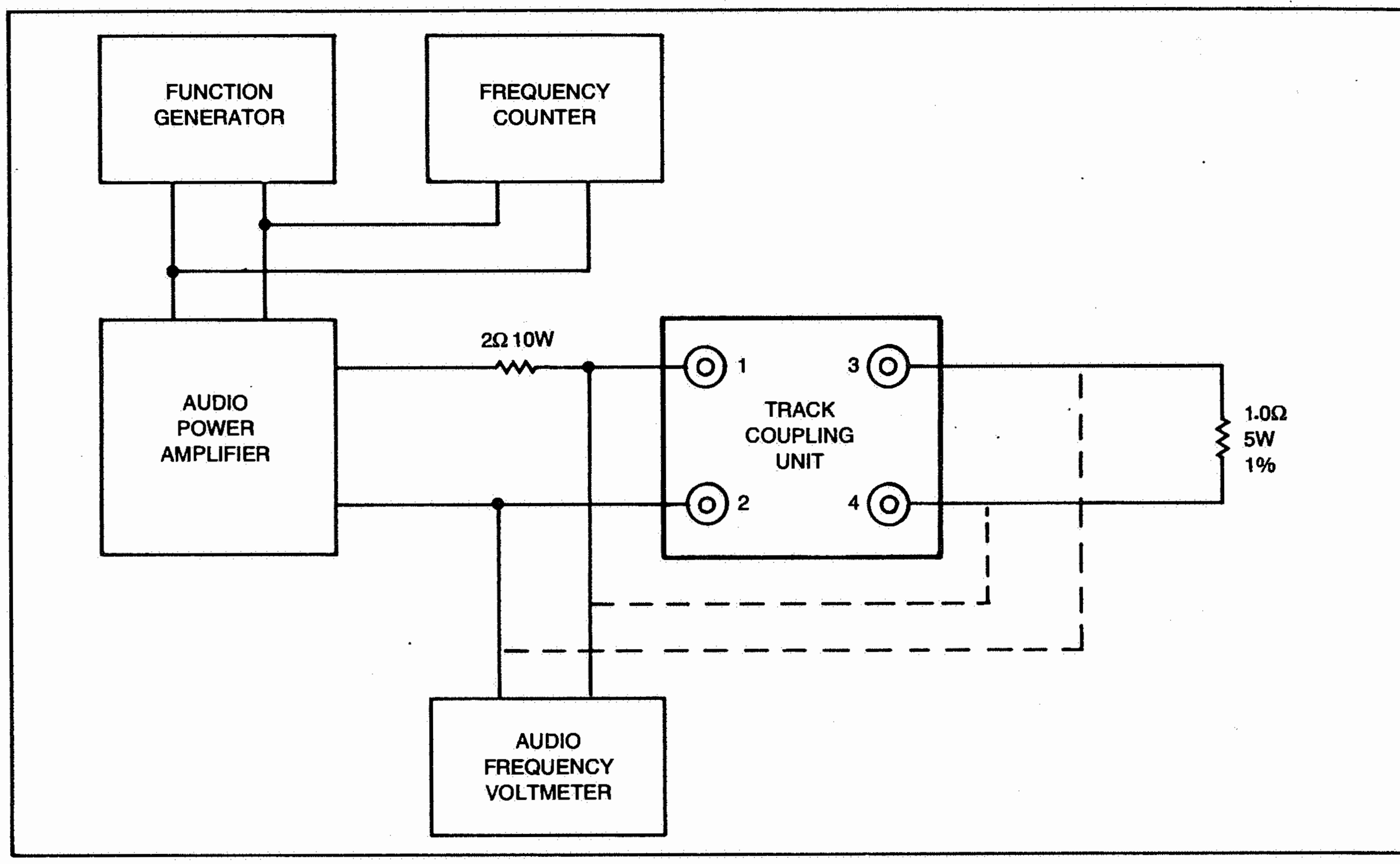

Figure 5-12. Track Coupling Unit Test Set-Up

5.4.4 Test Procedure

Operation	Verification
1. Adjust the audio power amplifier until the input level across AAR terminals 1 and 2 equals 1.0 ± .01 volts RMS.	1. --
2. Using the audio frequency voltmeter, measure the output level across the 1.0 ohm 5 watt load resistor.	2. The meter should show a reading between 0.29 and 0.75 volts RMS for units with suffix numbers -5801 and -5802, and 0.41 to 1.0 volts RMS for for units with suffix numbers -5803 and -5804. If this test is not successful, continue with step 3.

Operation		Verification	
3.	Using the vernier control on the function generator, adjust frequency until the output level across the 1.0 ohm load resistor is at a maximum (peaked).	3.	The frequency which creates a maximum output should be within 0.7% of the selected frequency of the unit under test. If this test is not successful continue with step 4.
4.	Readjust input level per Step 1.	4.	--
5.	Repeat Step 2.	5.	Same as step 2.

5.4.5 Procedure Follow-Up

Failure of the coupling unit to meet the frequency or output level specifications can be attributed to any of the components in the unit. The most likely are the capacitors. A coupling unit that fails the above tests should be returned to US&S for repair and recalibration. No attempt should be made to replace components and return the unit to service.

5.5 BLOCKING REACTOR

The AFO Blocking Reactor is not serviceable, either in the field or at the factory. If defective, it should be replaced with a new unit.

SERVICE MANUAL 6134

Appendix A

Parts List

for

AFO–IIC

Audio Frequency Overlay System

and

Support Equipment

DECEMBER, 1984 (Rev. June, 1985)
ID0001F-DN0003F
B-6/85-250-2314-1
RINTED IN USA

UNION SWITCH & SIGNAL DIVISION
AMERICAN STANDARD INC. / SWISSVALE, PA 15218

A.1 UNIT PART NUMBERS

A.1.1 Frequency-Classed Units

Frequency Range (Hz)		AFO-IIC Transmitter	AFO-IIC Receiver	Track Coupling Unit			
Carrier	Mod.	N451052-	N451052-	N451052- (Groups) #1	#2	#3	#4
870	18	2965	3165	--	--	--	--
885	18	2966	3166	1901	1902	1903	1904
930	18	2967	3167	1901	1902	1903	1904
945	18	2968	3168	1901	1902	1903	1904
980	22	2969	3169	1901	--	1903	--
1050	22	2970	3170	1901	--	1903	--
1120	22	2971	3171	--	1902	--	--
1180	22	2972	3172	--	--	1903	1904
1215	22	2973	3173	--	--	1903	1904
1285	27	2974	3174	1901	--	1903	--
1330	27	2975	3175	--	1902	--	1904
1420	27	2976	3176	--	1902	--	1904
1520	27	2977	3177	--	1902	--	1904
1660	27	2978	3178	--	--	1903	--
1860	39	2979	3179	1901	--	1903	--
1945	39	2980	3180	1901	--	1903	--
2140	39	2981	3181	--	1902	--	--
2365	49	2982	3182	--	--	--	1904
2540	49	2983	3183	1901	--	--	--
2720	49	2984	3184	--	1902	--	--
3360	68	2985	3185	1901	1902	--	--
3410	68	2986	3186	1901	1902	--	--
4565	94	2987	3187	--	--	--	--

A.1.2 Miscellaneous Units

Item	Description	US&S Part No.
Blocking Reactor	All AFO-IIC Frequencies	N451036-0302
Blocking Reactor	All AFO-IIC Frequencies (Microcode Application)	N451036-1701
Surge Ripple Filter	12 Vdc/2.5 amps	N451036-0702
Lightning Arrester	32 Vdc/25 Vac	N451552-0101
Lightning Arrester	250 Vdc/175 Vac	N451552-0201
Lightning Arrester	32 Vdc/25 Vac, W/Term. Block	X451552-0301
Lightning Arrester	250 Vdc/175 Vac, W Term. Block	X451552-0302

A.2 AFO-IIC RECEIVER BASIC ASSEMBLY (See Figure A-1)

Item	Description	US&S Part No.
1	Box	R451053-5101
2	Bracket, Support	R451053-5201
3	Cover	M451053-6001
4	Bracket, Mounting	M451053-5501
5	Block, Terminal	M181830
6	Holder, Fuse	J071889
7	Fuse, 1/8 Amp	J071075
8	Grommet	J751173
9	Screw, 10-32 x 5/8 Rd. Stl.	J052566
10	Washer, #10 Lk. Stl.	J047733
11	Nut, 10-32 Hex. Stl.	J048172
12	Potentiometer, 100K Ohm, 1/4 W (R2)	J620850-0057
13	Screw, 1/4-20 x 1/2 Rd. Stl.	J052642
14	Washer, 1/4 Lk. Stl.	J047775
15	Nut, 1/4-20 Hex Stl.	J480265
16	Screw, 10-32 x 1/2 Rd. Stl.	J052565
17	Washer	J047818
18	Nut, 14-24, Hex, Brass	J480300
19	Terminal	J730044
20	Nut, 14-24 Hex, Brass	J480301
21	Screw, 6-32 x 1/4 Rd. Stl.	J525055
22	Washer, 6 Shakeproof Lk. Stl.	J047713
23	Washer, 3/8 Lk. Int. Tooth Steel	J475210
25	Wire, #20 (Red)	A045219-0002
26	Wire, #20 (White)	A045219-0003
27	Wire, #20 (Orange)	A045219-0004
28	Wire, #20 (Blue)	A045219-0006
29	Wire, #20 (Yellow)	A045219-0007
30	Wire, #20 (Brown)	A045219-0009
31	Wire, #20 (Black)	A045219-0001
32	Wire, #20 (Green)	A045219-0005
33	Wire, #20 (Violet)	A045219-0010
34	PCB, Input Filter	N451522-53XX*
35	PCB, Demodulator/Input Driver	N451522-68XX**

* Refer to section A.3.2 for part numbers
**Refer to section A.3.4 for part numbers

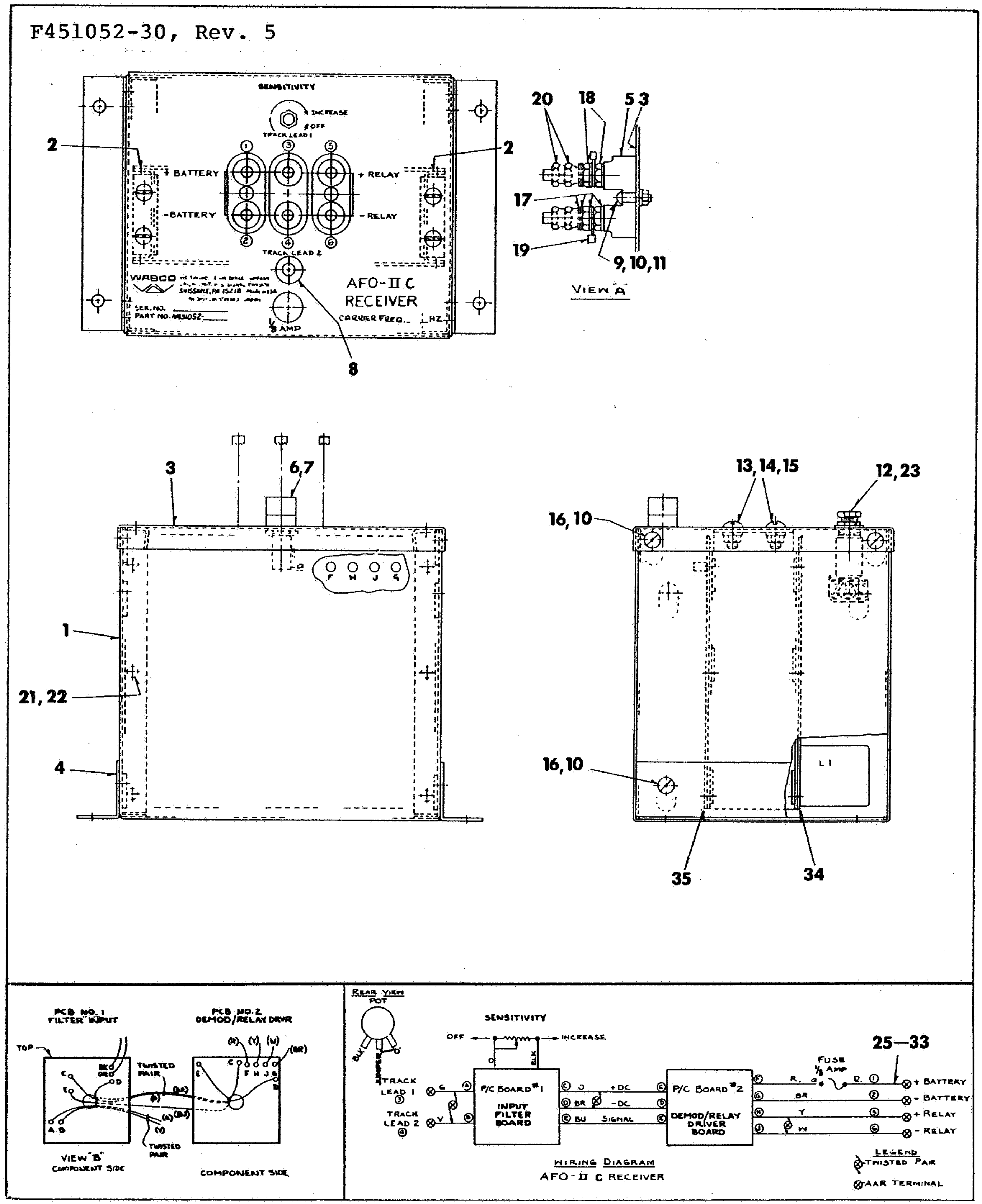

Figure A-1. AFO-IIC Receiver Basic Assembly and Chassis Wiring

A.3 RECEIVER PRINTED CIRCUIT BOARDS

A.3.1 Standard Vs. Frequency-Determining Components

The parts listed in this section are divided into "Standard" and "Frequency-Determining" cateogories. Standard components have the same operating values for all boards, regardless of the selected frequencies. Frequency-Determining components have variable operating values to define the frequency and modulation rate of the board. These are listed according to the defined frequency and basic part number for the board.

A.3.2 Input Filter PCB N451522-5302 to -5321, Standard Components (See Figure A-2)

Item	Description	US&S Part No.
C1,C2,C3 C4,C5	Capacitor	*
C6	Capacitor, 0.022 mFd, 10%, 100 Vdc	J706844
CX	Capacitor, TBD	--
C7	Capacitor, 0.1 mfd, 200 Vdc	J702280
C8	Capacitor, 0.1 mfd, 200 Vdc, 4LD	J709145-0211
C9	Capacitor, 10 mfd, 20 WVdc	J706373
D1	Diode, Schottky, 1N6263	J726150-0127
D2	Diode, 1N914A	J726031
L1,T2,L3 T4,T5	Inductor	*
R1	Resistor, 1.2K Ohms, 5%, 1/4W	J735519-0342
R3	Resistor, TBD	--
R4	Resistor, 5.6K Ohms, 5%, 1/4W	J735519-0343
R5	Varistor, Disc, 1/4 W, 15 Vdc	J735534
R6	Resistor	*
R7	Resistor, 270K Ohms, 5%, 1/2 W	J720760
R8	Resistor, 2.7 Megohm, 5%, 1/2 W	J735519-0074
R9, R10	Resistor, 820K Ohms, 5%, 1/2 W	J720776
R11	Resistor, 100K Ohms, 5%, 1/2 W	J720838
R12	Resistor, TBD	--
R13	Resistor, 1 Megohm, 5%, 1/4 W	J735519-0345
R14	Resistor, TBD	--
R15	Resistor, 13K Ohms, 5% 1/2 W	J735254
R16	Resistor, 2.7K Ohms, 5%, 1/4 W, 4 Ter.	J735519-0319
R17	Resistor, 22K Ohms, 5%, 1/4 W, 4 Ter.	J735519-0360
R18	Resistor, TBD	--
R19	Resistor, 2K Ohms, 5%, 1/2 W	J721080
Q1, Q2	Transistor, 2N5962-18	J731398-0040

*Frequency-Determining part; refer to section A.3.3 for part numbers.
TBD values determined during assembly and testing.

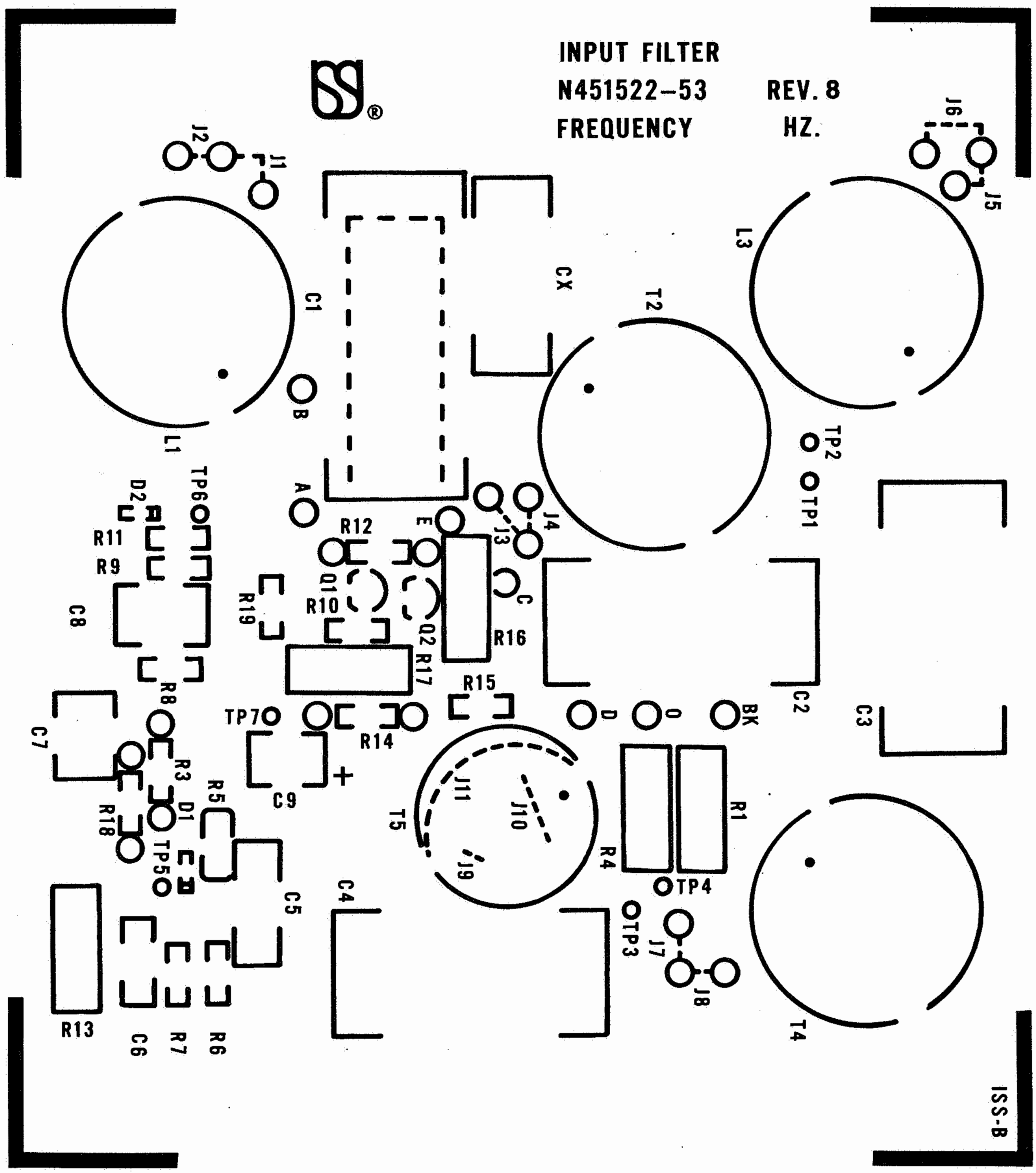

Figure A-2. Input Filter PCB Component Layout

A.3.3 Input Filter PCB N451522-5302 to -5321, Frequency-Determining Components

SUFFIX USING BASIC BOARD-5301	CARRIER FREQUENCY (HZ.)	JUMPER SEE NOTE	MODULATION FREQUENCY (HZ.)	INDUCTOR L1 WITH CAPACITOR C1 D451030	SH.	CAPACITOR C1 (FOR REF. ONLY) PART NO.	µf	INDUCTOR T2 WITH CAPACITOR C2 D451030	SH.	INDUCTOR L3 WITH CAPACITOR C3 D451030	SH.	INDUCTOR T4 WITH CAPACITOR C4 D451030	SH.	CAPACITORS C2, C3 & C4 (FOR REF. ONLY) PART NO.	µf	INDUCTOR T5 WITH CAPACITOR C5 D451030	SH.	CAPACITOR C5 (FOR REF. ONLY) PART NO.	µf	RESISTOR R6 PART NO.	OHMS
-5302	800-836 837-875 TAP	A B	18	N451030-5101	51	J709145-0347	10	N451030-5121	51	N451030-5001	50	N451030-5021	50	J709145-0338	.33	N451030-4901	49	J709145-0035	.015	J720775	8.2K
-5303	876-916 917-960 TAP	A B	18	-5102		-0347	10	-5122		-5002		-5022		-0338	.33	-4902		-0035	.015	J721257	7.5K
-5304	961-1006 1007-1055 TAP	A B	22	-5103		-0347	10	-5123		-5003		-5023		-0338	.33	-4903		-0135	.012	J720893	6.8K
-5305	1056-1104 1105-1155 TAP	A B	22	-5104		-0346	8	-5124		-5004		-5024		-0338	.33	-4904		-0135	.012	J720771	6.2K
-5306	1156-1209 1210-1265 TAP	A B	22	-5105		-0345	6	-5125		-5005		-5025		-0338	.33	-4905		-0135	.012	J720768	5.6K
-5307	1266-1323 1324-1385 TAP	A B	27	-5106		-0345	6	-5126		-5006		-5026		-0057	.283	-4906		-0134	.01	J721179	5.1K
-5308	1386-1450 1451-1520 TAP	A B	27	-5107		-0345	6	-5127		-5007		-5027		-0057	.283	-4907		-0134	.01	J720892	4.7K
-5309	1521-1591 1592-1665 TAP	A B	27	-5108		-0344	5	-5128		-5008		-5028		-0057	.283	-4908		-0134	.01	J723005	4.3K
-5310	1666-1744 1745-1825 TAP	A B	39	-5109		-0345	6	-5129		-5009		-5029		-0337	.22	-4909		-0133	.0082	J720764	3.9K
-5311	1825-1910 1911-2000 TAP	A B	39	-5110		-0344	5	-5130		-5010		-5030		-0337	.22	-4910		-0132	.0068	J721191	3.6K
-5312	2001-2093 2094-2190 TAP	A B	39	-5111		-0343	4	-5131		-5011		-5031		-0337	.22	-4911		-0132	.0068	J720888	3.3K
-5313	219 - 2293 2794-2400 TAP	A B	49	-5112		-0943	4	-5132		-5012		-5032		-0054	.189	-4912		-0131	.0056	J721256	3.0K
-5314	2401-2512 2513-2650 TAP	A B	49	-5113		-0342	3.5	-5133		-5013		-5033		-0054	.189	-4913		-0131	.0056	J720758	2.7K
-5315	265 - 2754 2755-2885 TAP	A B	49	-5114		-0341	3	-5134		-5014		-5034		-0138	.15	-4914		-0130	.0047	J721255	2.4K
-5316	2886-3020 3021-3160 TAP	A B	68	-5115		-0342	3.5	-5135		-5015		-5035		-0262	.1	-4915		-0130	.0047	J720842	2.2K
-5317	3161-3308 3309-3465 TAP	A B	68	-5116		-0341	3	-5136		-5016		-5036		-0154	.12	-4916		-0128	.0039	J721080	2.0K
-5318	3466-3629 3630-3800 TAP	A B	68	-5117		-0340	2.5	-5137		-5017		-5037		-0154	.12	-4917		-0128	.0039	J720825	1.8K
-5319	3801-3976 3977-4160 TAP	A B	94	-5118		-0340	2.5	-5138		-5018		-5038		-0154	.12	-4918		-0082	.0033	J721254	1.6K
-5320	4161-4354 4355-4560 TAP	A B	94	-5119		-0340	2.5	-5139		-5019		-5039		-0262	.1	-4919		-0072	.003	J721064	1.5K
-5321	2561-4775 4776-5000 TAP	A B	94	N451030-5120	51	J709145-0339	2	N451030-5140	51	N451030-5020	50	N451030-5040	50	J709145-0149	.082	N451030-4920	49	J709145-0072	.003	J723065	1.3K

A.3.4 Demodulator/Relay Driver PCB N451522-6802 to -6808, Standard Components (See Figure A-3)

Item	Description	US&S Part No.
C1, 2	Capacitor	*
C3, 5	Capacitor, 47 mFd, 10%, 20 Vdc	J706254
C4, 6	Capacitor, 100 mFd, 10%, 20 Vdc	J706416
C7, 8, 9, 10	Capacitor, 0.01 mFd, 5%, 100 Vdc	J706589
C11	Capacitor, 0.068 mFd, 5%, 100 Vdc	J706569
C12, 13	Capacitor, 1 mFd, 10%, 35 Vdc	J706387
C14,15,16	Capacitor, 0.01 mFd, 500 V	J706647
C17	Capacitor, 0.005 mFd, 400 V	J709145-0011
D1, 2, 3, 5	Diode, 1N4003	J723555
D4	Diode, Zener, 1N748A, 3.9 Vdc, 5%	J726150-0071
D6, 7	Diode, 1N281	J723881
IC1	Operational Amplifier LM224J	J715029-0262
L1	Inductor, 10,000 micro-H	J703315
L2 thru L8	Inductor	J709602
Q1, 2	Transistor, 2N5962-18	J731398-0040
Q3	Transistor, PN3644-5	J731283
Q4	Transistor, 2N2270	J731186
Q5	Transistor, 2N4037	J731291
R1, 2, 3, 4, 9	Resistor, 38.3K Ohms, 1%, 1/4 W	J735519-0350
R5, 10	Resistor, TBD	--
R6	Resistor, 20K Ohms, 1%, 1/4 W	J735519-0351
R7	Resistor, 1 Megohm, 5%, 1/2 W	J735519-0345
R8, 11	Resistor, 39K Ohms, 5%, 1/2 W	J720765
R12, 13	Resistor, 4.42K Ohms, 1%, 1/2 W	J735519-0173
R14	Resistor, 20 Ohms, 5%, 1/2 W	J072276
R15	Resistor, 1K Ohms, 5%, 1/2 W	J720882
R16, 17	Resistor, 100K Ohms, 5%, 1/2 W	J720838
R18, 22, 23, 24	Resistor, 10K Ohms, 5%, 1/2 W	J720883
R19, 25	Resistor, 470 Ohms, 5%, 1/2 W	J721065
R20	Resistor, 2.2 Megohm, 5%, 1/2 W	J720845
R21	Resistor, 1 Megohm, 5%, 1/2 W	J720839

*Frequency-Determining part; refer to section A.3.5 for part numbers.
TBD-Values determined during assembly and testing.

A.3.5 Demodulator/Relay Driver PCB N451522-6802 to -6808, Frequency-Determining Components

PCB (Basic: -6801)	Modulation Frequency (Hz)	Capacitors C1, C2 Description	US&S Part No.
-6802	18	0.22 mFd.	J709145-0337
-6803	22	0.18 mFd.	J709145-0139
-6804	27	0.15 mFd.	J709145-0138
-6805	39	0.10 mFd.	J709145-0262
-6806	49	0.082 mFd.	J709145-0149
-6807	68	0.056 mFd.	J709145-0073
-6808	94	0.039 mFd.	J709145-0150

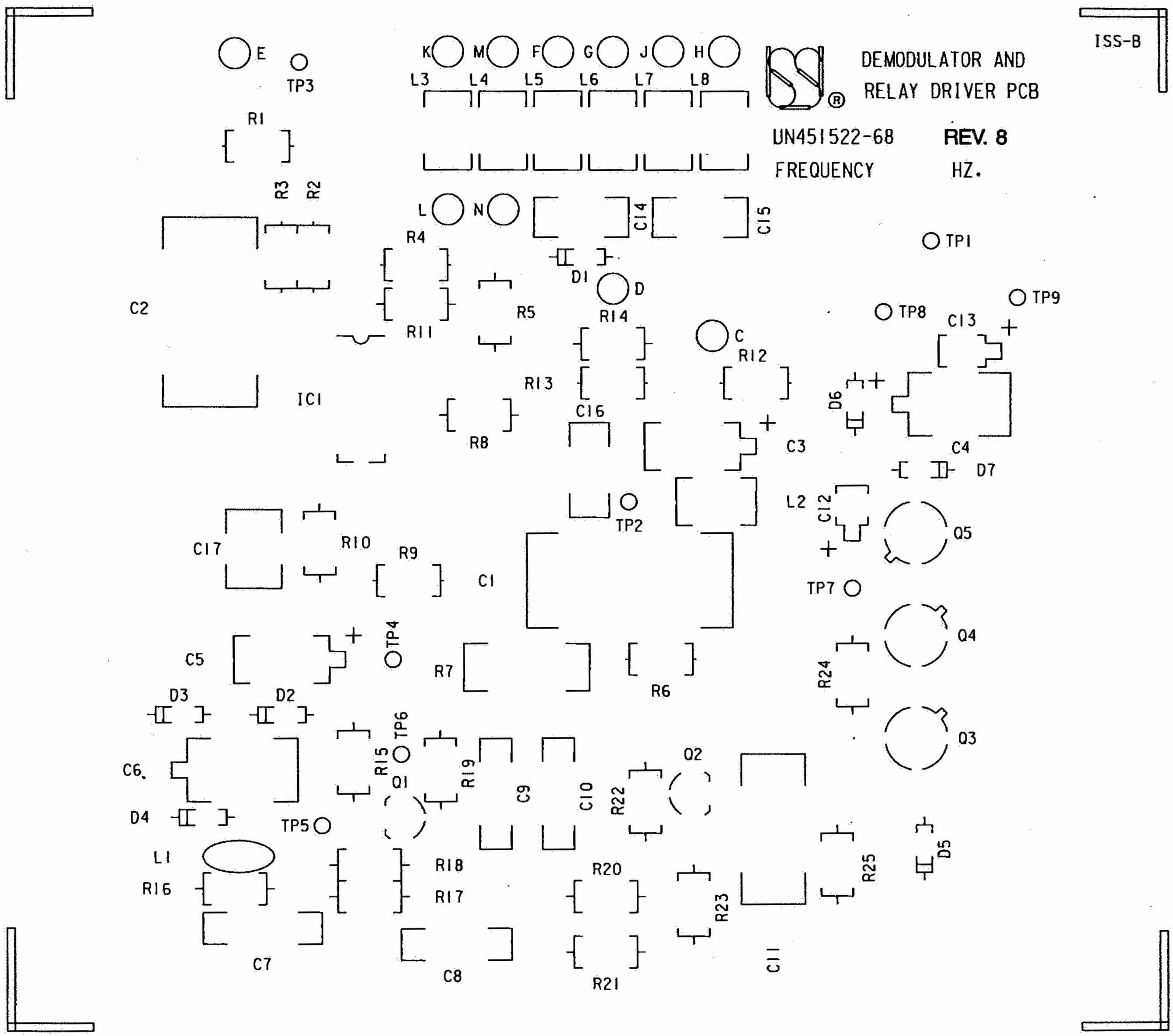

Figure A-3. Demodulator/Input Driver PCB Component Layout

A.4 AFO-IIC TRANSMITTER BASIC ASSEMBLY (See Figure A-4)

Item	Description	US&S Part No.
1	Box	R451053-5101
2	Bracket, Support	R451053-5201
3	Cover	M451053-5603
4	Bracket, Mounting	M451053-5501
5	Block, Terminal	M181831
6	Holder, Fuse	J071889
7	Fuse, 2 Amp	J710026
8	Grommet	J751169
9	Screw, 10-32 x 5/8 Rd. Stl.	J052566
10	Washer, #10 Lk. Stl.	J047733
11	Nut, 10-32 Hex. Stl.	J048172
12	Screw, 1/4-20 x 1/2 Rd. Stl.	J052642
13	Washer, 1/4 Lk. Stl.	J047775
14	Nut, 1/4-20 Hex Stl.	J480265
15	Screw, 10-32 x 1/2 Rd. Stl.	J052565
16	Washer	J047818
17	Nut, 14-24, Hex, Brass	J480300
18	Terminal	J730044
19	Nut, 14-24, Hex, Brass	J480301
20	Screw, 6-32 x 1/4 Rd. Stl.	J525055
21	Washer, 6 Shakeproof Lk. Stl.	J047713
23	Wire, #20 (Red)	A045219-0002
24	Wire, #20 (White)	A045219-0003
25	Wire, #20 (Brown)	A045219-0009
26	Wire, #20 (Yellow)	A045219-0007
27	Transmitter PCB	*

*Refer to section A.4.X for part numbers.

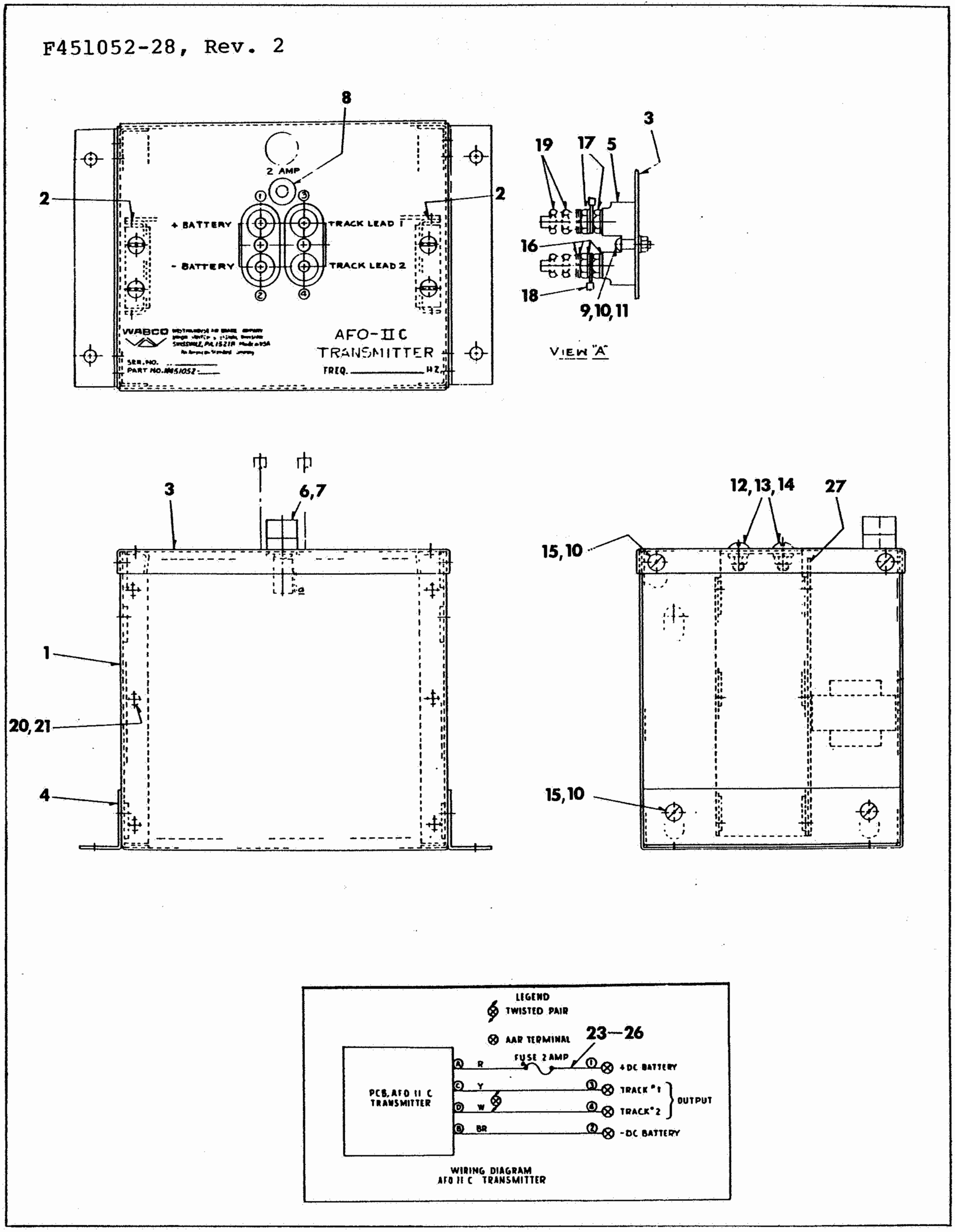

Figure A-4. AFO-IIC Transmitter Basic Assembly and Chassis Wiring

A.5 TRANSMITTER PRINTED CIRCUIT BOARD

NOTE

Refer to section A.3.1 for description of "Standard" vs. "Frequency-Determining" components.

A.5.1 Transmitter PCB N451522-4502 to -4521, Standard Components (See Figure A-5)

Item	Description	US&S Part No.
C1, 5	Capacitor	*
C2, 3	Capacitor, 0.1 mFd, 5%, 200 Vdc	J706827
C4	Capacitor, 0.22 mFd, 5%, 200 Vdc	J709144-0091
C6	Capacitor, 0.82 mFd, 10%, 50 Vdc	J709145-0328
C7	Capacitor, 82 pFd, 5%, 300 Vdc	J706939
C8, 13	Capacitor, 15 mFd, 10%, 20 Vdc	J706891
C9, 10, 12	Capacitor, 0.0033 mFd, 2%, 200 Vdc	J709145-0082
C11, 11A	Capacitor	*
C13	Capacitor, 100 mFd, Tant, 10%, 20 Vdc	J706416
D1	Diode, Zener, 1N4730A, 3.9 Vdc	J726150-0120
D2, 4, 5	Diode, 1N4003	J723555
D3	Diode, G1432	J723881
IC1	Operational Amplifier, 3160T	J715029-0223
IC2	Operational Amplifier, 3130T	J715029-0128
L1	Inductor	*
L2	Inductor	*
Q1, 3	Transistor, 2N5087	J731398-0027
Q2	Transistor, 2N5210	J731398-0026
Q4	Transistor, 2N2270	J731186
Q5	Transistor, 2N4037	J731291
Q6, 7	Transistor, MJ1000	J731427
R1	Resistor, 120 Ohms, 5%, 2 W	J735519-0058
R2	Resistor, 3.3K Ohms, 5%, 1/2 W	J720888
R3, 9, 15	Resistor, 10K Ohms, 5%, 1/2 W	J720883
R4, 5	Resistor	*
R6, 6A	Resistor, TBD	--
R7, 7A	Resistor, TBD	--
R8	Resistor, 47K Ohms, 5%, 1/2 W	J720846
R10	Resistor, 1K Ohm, 5%, 1/2 W	J720882
R11, 11A	Resistor, TBD	--
R12	Resistor, 330K Ohms, 5%, 1/2 W	J720890
R13	Resistor, 150K Ohms, 5%, 1/2 W	J720840
R14, 16	Resistor, 15K Ohms, 5%, 1/2 W	J720885
R17	Resistor, 100 Ohms, 5%, 1/2 W	J721194
R18	Resistor, 30 Ohms, 5%, 1/2 W	J723586
T1	Transformer	*
T2	Transformer	N451030-3551
T3	Transformer	N451039-3801

*Frequency-Determining part; refer to section A.5.2 for part numbers.

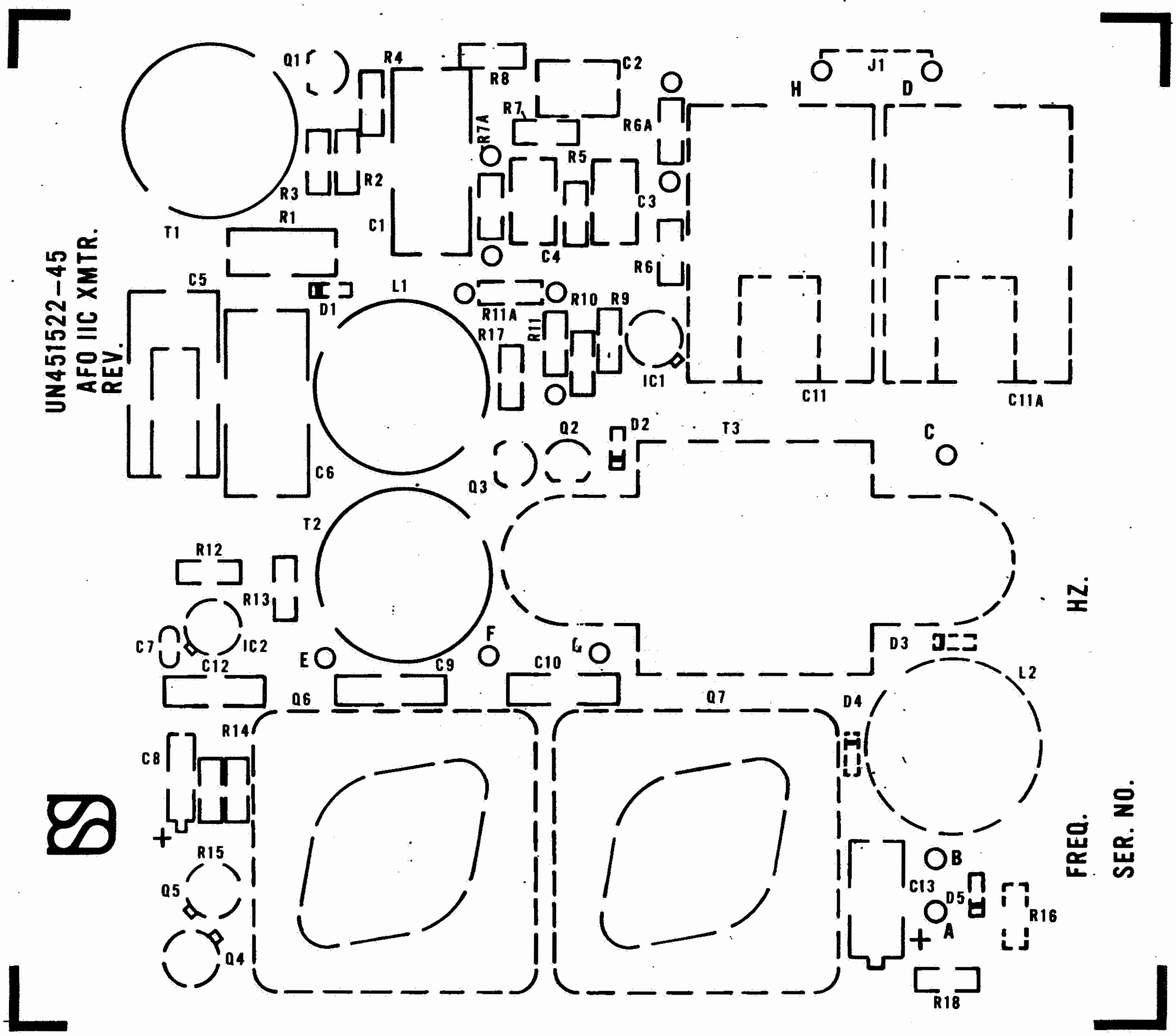

Figure A-5. Transmitter PCB Component Layout

A.5.2 Transmitter PCB N451522-4502 to -4521, Frequency-Determining Components

SUFFIX	FREQ HZ	BASIC BD	R4		R5		C1, C5		C11		C11A		L1		L2		T1	
			PART NO	OHM	PART NO	OHM	PART NO	MFD	PART NO	MFD	PART NO	MFD	D451030	SH.	D451030	SH.	D451030	SH.
-4502	800 TO 875	N451522-4501	J721064	1.5K	J720775	8.2K	J706743	.22	J709033	10	J709033	10	N451030-4408	44	N451030-4448	44	N451030-4428	44
-4503	876 TO 960	↑	J721064	1.5K	J720775	8.2K	J706743	.22	J709033	10	J709033	10	↑ -4409	↑	↑ -4448	↑	↑ -4429	
-4504	961 TO 1055		J721064	1.5K	J720893	6.8K	J706743	.22	J709033	10	J706816	8	-4410		-4449		-4430	
-4505	1056 TO 1155		J721080	2K	J720893	6.8K	J706743	.22	J706816	8	J706816	8	-4411		-4449		-4431	
-4506	1156 TO 1265		J721080	2K	J720893	6.8K	J706562	.12	J706816	8	J706838	5	-4412		-4449		-4432	
-4507	1266 TO 1385		J721080	2K	J720768	5.6K	J706562	.12	J706816	8	J706838	5	-4413		-4450		-4433	
-4508	1386 TO 1520		J721064	1.5K	J720768	5.6K	J706562	.12	J706816	8	J709034	3	-4414		-4450		-4434	
-4509	1521 TO 1665		J721064	1.5K	J720768	5.6K	J706562	.12	J706838	5	J706817	4	-4415		-4450		-4435	
-4510	1666 TO 1825		J721080	2K	J720764	3.9K	J706549	.033	J706838	5	J706817	4	-4416		-4451		-4436	
-4511	1826 TO 2000		J721080	2K	J720764	3.9K	J706549	.033	J706817	4	J709034	3	-4417		-4451		-4437	
-4512	2001 TO 2190		J721080	2K	J720764	3.9K	J706549	.033	J706838	5	—	—	-4418		-4451		-4438	
-4513	2191 TO 2400		J720888	3.3K	J720888	3.3K	J706549	.033	J706817	4	J709034	3	-4419		-4452		-4439	
-4514	2401 TO 2630		J720888	3.3K	J720888	3.3K	J706549	.033	J706838	5	—	—	-4420		-4452		-4440	
-4515	2631 TO 2885		J720888	3.3K	J720888	3.3K	J706549	.033	J706838	5	—	—	-4421		-4452		-4441	
-4516	2886 TO 3160		J720888	3.3K	J721255	2.4K	J706549	.033	J706838	5	—	—	-4422		-4453		-4442	
-4517	3161 TO 3465		J720888	3.3K	J721255	2.4K	J706549	.033	J706817	4	—	—	-4423		-4453		-4443	
-4518	3466 TO 3800		J720888	3.3K	J721255	2.4K	J706549	.033	J709034	3	J709056	.33	-4424		-4453		-4444	
-4519	3801 TO 4160		J720888	3.3K	J721254	1.6K	J706549	.033	J706838	5	—	—	-4425		-4454		-4445	
-4520	4161 TO 4560	↓	J720888	3.3K	J721254	1.6K	J706549	.033	J706838	5	—	—	↓ -4426	↓	↓ -4454	↓	↓ -4446	
-4521	4561 TO 5000	N451522-4501	J720888	3.3K	J721254	1.6K	J706549	.033	J709034	3	J709056	.33	N451030-4427	44	N451030-4454	44	N451030-4447	44

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A.6 TRACK COUPLING UNIT BASIC ASSEMBLY (See Figure A-6)

Item	Description	US&S Part No.
1	Box	R451053-5101
2	Bracket, Support	R451053-5201
3	Cover	M451053-5602
4	Bracket, Mounting	M451053-5501
5	Block, Terminal	M181831
6	Board, Component	*
7	Grommet, Rubber, 1/2 in.	J751169
8	Screw, 10-32 x 5/8 Rd. Stl.	J052566
9	Washer, #10 Lk. Stl.	J047733
10	Nut, 10-32 Hex. Stl.	J048172
11	Screw, 1/4-20 x 1/2 Rd. Stl.	J052642
12	Washer, 1/4 Lk. Stl.	J047775
13	Nut, 1/4-20 Hex Stl.	J480265
14	Screw, 10-32 x 1/2 Rd. Stl.	J052565
15	Washer	J047818
16	Nut, 14-24, Hex, Brass	J480300
17	Terminal	J730044
18	Nut, 14-24, Hex, Brass	J480301
19	Screw, 6-32 x 3/8 Rd. Stl.	J525031
20	Washer, #6 Shakeproof Lk., Stl.	J047713
22	Capacitors (Selected at Manufacture)	
	(1.0 mFd, 200 Vdc	J701760
	(0.5 mFd, 200 Vdc	J701073
	(0.1 mFd, 200 Vdc	J706181
	(0.05 mFd, 400 Vdc	J701573
	(0.01 mFd, 400 Vdc	J701572
--	Wire, #20 (Red)	A045219-0002
--	Wire, #20 (Orange)	A045219-0004
--	Wire, #20 (Yellow)	A045219-0007
--	Wire, #20 (Green)	A045219-0005

*Refer to section A.7.

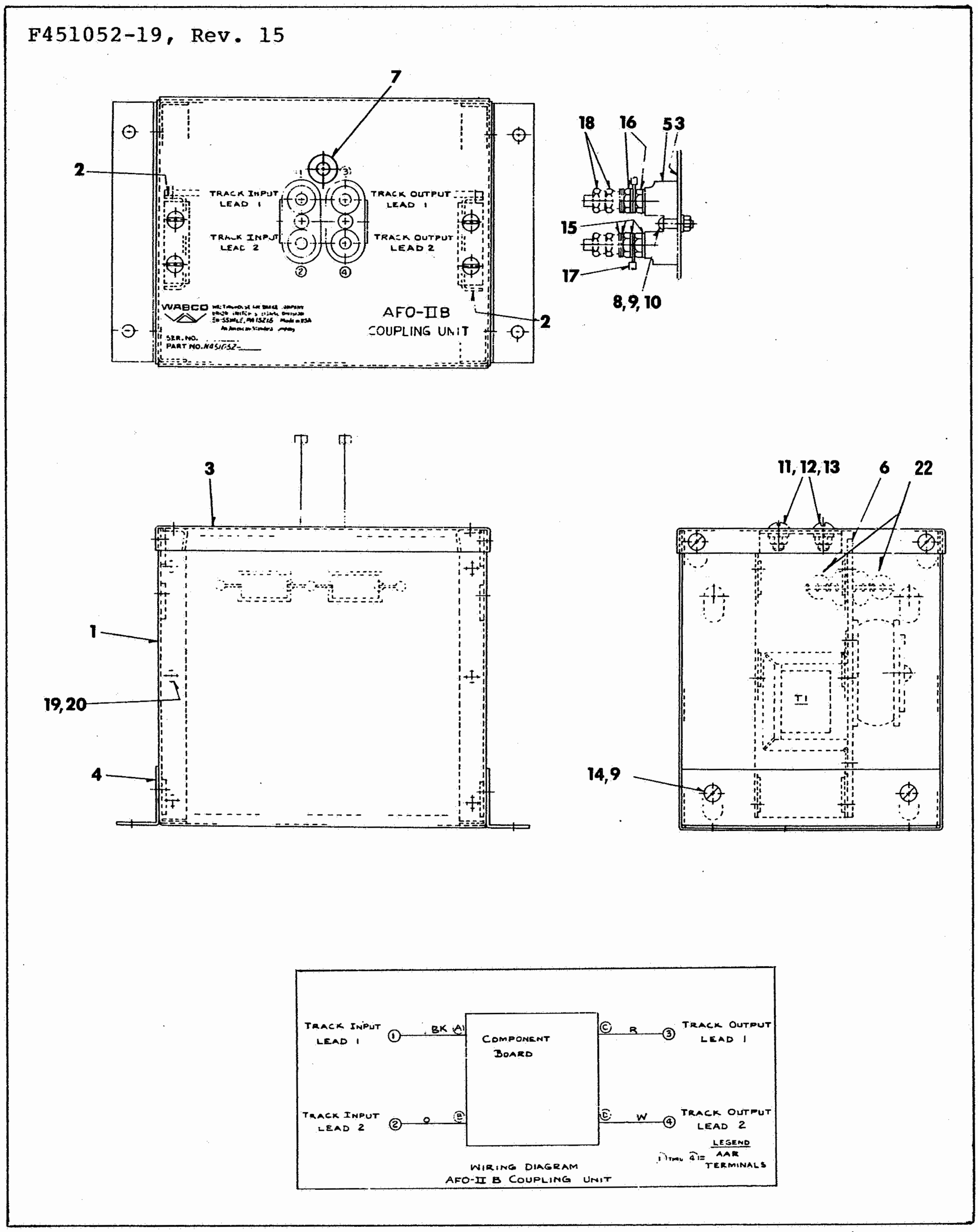

Figure A-6. Track Coupling Unit Basic Main Assembly and Chassis Wiring

A.7 TRACK COUPLING UNIT COMPONENT BOARD N451053-580X (See Figure A-7)

A.7.1 Standard Components

Item	Description	US&S Part No.
1	Turret Lug	M377206
2	Washer, Felt	M162571
3	Washer, Insulated	M328033
4	Screw, 10-32 x 3-1/2 Rd. Stl.	J052637
5	Washer, #10 Flt., Stl.	J457077
6	Washer, #10 Lk. Stl.	J047733
7	Nut, 10-32 Hex Stl.	J048172
8	Strip, terminal	J724317
9	Screw, 6-32 x 1 Rd. Stl.	J525097
10	Washer, #6 Flt. Stl.	J047996
11	Washer, #6 Lk. Stl.	J047662
12	Nut, 6-32 Hex Stl.	J048148
13	Transformer	N451039-1202
14	Screw, 8-32 x 1/2 Rd. Stl.	J052531
15	Washer, #8 Lk. Stl.	J047681
16	Nut, 8-32 Hex. Stl.	J048166
17	Terminal	J730039
18	Wire, #18 Teflex (White)	A045010-0004
19	Wire, #18 Teflex (Black)	A045010-0001
20	Wire, #18 Teflex (Red)	A045010-0003
21	Wire, #18 Teflex (Blue)	A045010-0005
22	Inductor, Torodial	*
23	Capacitor	*

*Frequency-determining part; refer to section A.7.2 for part numbers.

A.7.2 Frequency-Determining Components

Unit No. N451052-	PCB No. N451053-	Torodial Inductor (L1, L2)	Capacitor
1901	5801	N398916-001	C1, 3 (1.0 mFd, 200 Vdc): J701760 C2, 4 (2.0 mFd, 200 Vdc): J702617
1902	5802	N398916-002	C1, 3 (1.0 mFd, 200 Vdc): J701760 C2, 4 (2.0 mFd, 200 Vdc): J702617
1903	5803	N438610	C1,3 (10 mFd, 200 Vdc): J709033
1904	5804	N438610-001	C1,3 (10 mFd, 200 Vdc): J709033