SECTION 6

SYSTEM TESTING

6-1 SYSTEM MAKEUP

Although it is possible to divide systems functionally by operation, they may be simple systems such as transmit or receive types, or they can be complex ship-to-ship, ship-to-shore, transcontinental, global, etc. Each of these, in turn, is made up of other separate systems, for example, voice transmission systems, AM or FM; Data systems; Sonar or Radar systems; Facsimile or Teletypewriter systems; and Navigation systems such as LORAN, TACAN, and Satellite. Each of these systems is composed of certain groups of equipment or units. There are numerous types of systems tests, at least as many as there are systems. Only electronic systems will be discussed in this section.

6-2 SYSTEM TESTING PROCEDURES

The system testing approach is best accomplished by starting with the least complex integers of the system (e.g., transmitters, receivers, indicators), testing them and assuring their acceptability. These units can then be inserted into a larger system (e.g., radar, TACAN, link). The larger system is, in turn, tested for quality assurance, etc., until the entire system check is completed.

6-3 TYPES OF SYSTEMS TESTS

Systems tests are divided into overall performance tests, minimum performance tests, sensitivity tests, power input or power output tests, and other tests. Each of these tests can be used qualitatively to determine the condition of a system, a black box, or group of black boxes which comprise a system. By using general categories as the headings for these systems, they can be subdivided into specific groups. The general purpose of this section is to set forth the idea of using system tests for quick localization of trouble to an equipment. Thus, the technician is not concerned with finding the defective part in this instance, but rather in isolating the system and unit of equipment of which it forms a part. Ordinary voltage, resistance, and other simple tests are then used within the defective unit or box to find the part actually at fault.

6.3.1 TRANSMITTER SYSTEM TESTING

Most electronic systems encountered aboard ship are external systems; that is, they either receive their information transmitted to the ship, or they transmit information from the ship, with some systems performing both functions. To transmit accurate information from the ship, a reliable transmitter is required. To ensure reliability, the transmitter parameters that must be monitored include power output, voltage standing wave ratio (VSWR), frequency stability, modulation, and distortion products. Power output checks can be made by terminating the transmitter's output power by means of a power meter. This technique, however, is not always practical. Some systems, due to their complexity, can only be terminated into their designed antennas. In these instances, a directional coupler is either provided or can be inserted into the transmission line. A directional coupler usually has the added advantage of a port for measuring reflected power as well as incident power, thus enabling the VSWR to be computed. Frequency response, impedance, and power handling capabilities of the measuring instrument are the principal considerations in measuring a transmitter's output power. Frequency stability, modulation, and distortion products of the transmitted signal can be monitored by using a spectrum analyzer. The analyzer's pickup of the transmitted signal can be obtained thru a separate antenna system or thru a directional coupler inserted into the transmission line. The first method is preferable because the entire transmitting system, including the antenna, will thus be checked. However, this arrangement may not always prove practical. The type of transmitting system being monitored will determine which monitoring methods are most practical.

6-3.2 RECEIVER SYSTEM TESTING

Selectivity, sensitivity, or minimum discernible signal (MDS), and the noise figure are the most pertinent parameters measured on a receiver. Selectivity is a determination of how well a receiver can differentiate between two signals close in frequency, selecting the desired signal and rejecting the adjacent signal. Receiver sensitivity, MDS, and the noise figure are basically interrelated in that they all measure the same thing: namely, the receiver's ability to receive a weak signal and to reject unwanted frequencies. Bandwidths and frequency usually determine which method will be used to determine the degree of receiver sensitivity. Communication receivers operate between LF and UHF ranges, using a narrow bandwidth. The sensitivity parameter is the ratio of signal plus noise-to-noise (S+N/N). This serves as a measure of a receiver's ability to extract a weak signal out of atmospheric noise and then overcome the receiver's own internally generated noise. Minimum discernible signal measurements are usually accomplished on receivers with a visual indicator. Such receivers usually operate in the UHF range and above, and employ relatively wide bandwidths. The prime noise a weak signal must overcome in this system is receiver internal noise. Noise figure measurements are a measure of a receiver's RF and/or I-F internal noise that the received signal must override to be useful.

6-3.3 DISPLAY SYSTEM TESTING

Display systems are many-faceted. They can be mechanical, visual, aural, or any combination of these. Display systems provide the interface between the individual operator and the electronic system or systems. Display systems can be incorporated into a larger system on the transmit side, or on a receive side, or on both, or be independent of both. They can also be employed in multiple systems simultaneously. When a display system is used to check another system, such as a transmit or receive system, it must first be checked out itself and found to be functioning correctly, thus averting any fault ambiguity in further system testing. Mechanical display devices are primarily used in producing or reproducing printed or graphic information. Individual character alignment, stylus alignment and/or motor synchronization speed are the main concern of most mechanical display devices. Each individual type of mechanical display device's maintenance standard requirement card must be consulted for a more exacting checkout procedure of that particular type of device. Visual display devices are of three basic types: phosphorescents; light-emitting diode (LED); and liquid crystal devices (LCD). Phosphorescent devices are used in scanner displays, such as radar, sonar, television and computers, to obtain a pictorial presentation of the information of the particular system in which it is incorporated. The LEDs and LCDs are usually employed as alphanumerical readout devices, such as depth indicators on fathometers, and on-time and frequency indicators. Because of the non-commonality of visual display devices, the maintenance requirement pertinent to the system of which a device is a part must be consulted for adequate system checkout. Audio display devices are primarily used in voice communication. These are the least complex of display devices and the simplest to test. A convenient audio signal source is usually sufficient to test audio display devices.

6-3.4 INTERFACE AND CONTROL SYSTEM TESTING

The purpose of the interface and control system is the bridging and controlling of the different functional systems. This I & C system can be as simple as a SPST switch, or as complex as a computer. The two functions (controlling and interfacing) can operate either as separate systems independent of one another, or as a single broad system. Converting the signals of the receiver to those used to actuate a teleprinter, or converting the data from a computer for input into a transmitter, are the normal functions of an interface system. Changing the frequency of a transmitter or the pulse width of a radar from a remote location are typical functions of a control system. Control functions are usually switching functions, whereas interfacing is more likely to be some form of unit interconnection. Either system could be electronic, mechanical, or both in actual application. Specific test procedures applicable to the interface and control system cannot be addressed because each type of control and/or interface is unique. Each system is designed to meet a requirement that cannot satisfactorily be accomplished by any other existing unit. In general, there are three tests that can be made to just about any interface system: an input test; a connection test; and an output test. The basic test that is made to a control system involves ensuring the operability of the switching actuator, whether it be mechanical or electronic. However, in some instances, switch alignment tests are necessary. Switch alignment entails the setting of operational precedence in a sequential or stepping switching system so that one set of conditions is met before another is attained or before an operator can proceed.

6-4 INTERSYSTEM TEST

The flow of signals normally requires two or more systems interconnected to comprise a larger system. A radar without an appropriate indicator is of no value when trying to plot intercept aircraft; similarly, broadcast signals intercepted by a receiver must be processed into functional data for application to the various teleprinter configurations. These are only two examples of multiple systems working as a single entity or system. A test of the individual system, which now forms the components of a must larger system, may not always reveal a problem area.

Junction boxes and interconnecting cables now exist which join the "components" of the system together and can contribute to problem areas. In some instances, locating interconnecting problems can be accomplished with an intersystem test. The system configuration will dictate which intersystem test (if any) is applicable.

6-4.1 BACK-TO-BACK TEST

When one system's output can be connected directly to, or transmitted into, another system input, or vice-versa, back-to-back testing can be performed, provided the two systems are identical in functional design. Both systems must be two-way message transfer systems; that is, they must be capable of transmitting information as well as receiving information. Such transfer of information from one system to another is done one at a time — it cannot be accomplished simultaneously. Figure 6-1 illustrates a back-to-back set-up in an uncovered teletype system. The three dashed lines indicate back-to-back hook-up possibilities. If the teleprinters are only to be tested, Line One would be connected and the converters disconnected. Whatever is typed on the teleprinter in system "A" would then be reproduced on the teleprinter in system "B" and vice-versa. The same would also be true if, instead of Line One, Lines Two or Three are connected. (Note: Line Three would be received via the antenna or through a proximity pick-up located near a dummy load.) A more comprehensive test of the system would be realized by utilizing Line Two instead of Line One; and the most comprehensive test of the system will be realized by utilizing Line Three instead of Line Two. Figure 6-1 illustrates a simple system. More components can be inserted into the system, yet the test will still be valid provided the systems remain identical in function. Back-to-back tests are limited by the accessibility or availability of the equipment needed to perform the test. Although equipment is not required in back-to-back

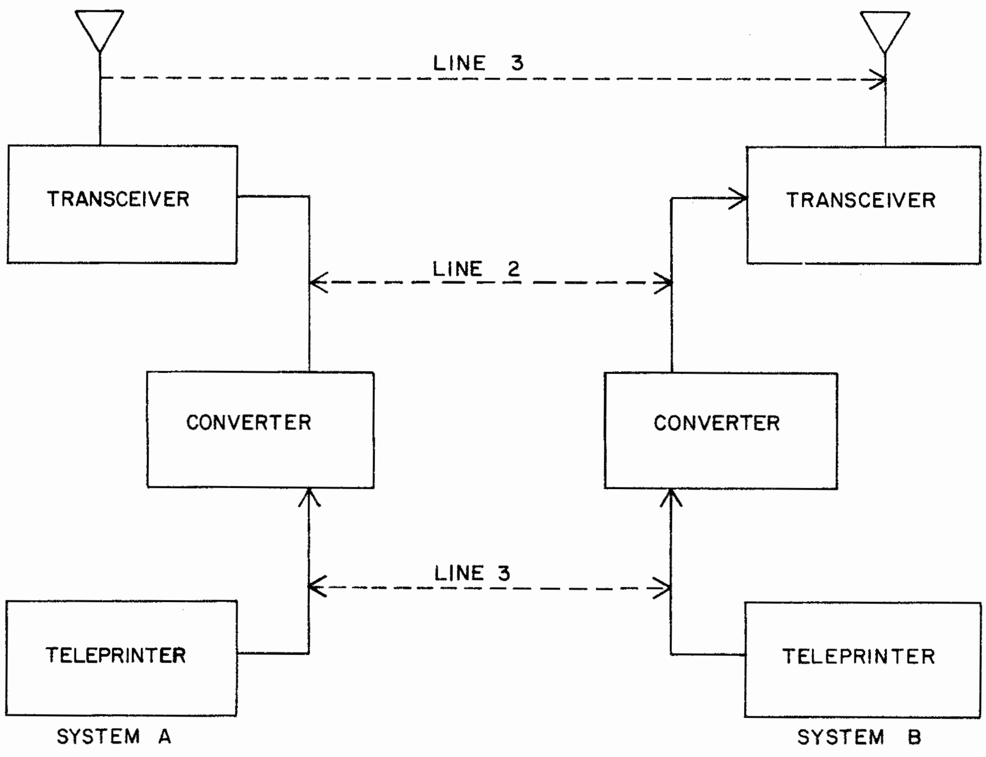


Figure 6-1. A Back-To-Back System Test Configuration

testing, a working knowledge of how to align the two systems is essential. Some manufacturers provide, with the equipment, the connecting devices needed to perform back-to-back tests. When such devices are not included, they can usually be procured or fabricated locally.

6-4.2 END AROUND TEST

The "end around" test is similar to the back-to-back test in that the system's output is fed back into the input. The principal difference is that only one system is used. This test is employed primarily in the larger, one-of-a-kind systems on board ship, and is normally provided for in the design of the system. Figure 6-2 illustrates a typical "end around" test configuration. The first step in utilizing the configuration involves loading the computer with the test function. However, this is only necessary in systems where the computer's memory bank is not large enough to accommodate the test program as well as the operational program. The test command is then given to the computer via the input/output terminal equipment. If the system is properly aligned, the computer will cause the terminal equipment to print out the results of the test. Figure 6-2 illustrates that progressive qualitative tests of the system can be made by switching first to a Line One test, then to Line Two, and ultimately to Line Three for a comprehensive test of the entire system. In each condition of "end around" (Lines One, Two and Three) the entire test program must be run to realize any realistic comparison of system performance.

6-4.3 OFF-SHIP SYSTEM TESTING

Some systems do not lend themselves to a complete checkout within the ship environment. Systems such as TACAN and some of the other active systems on board the ship must be checked out by radiating signals to an off-ship testing station. The test results are then fed back to the ship for analyzation.

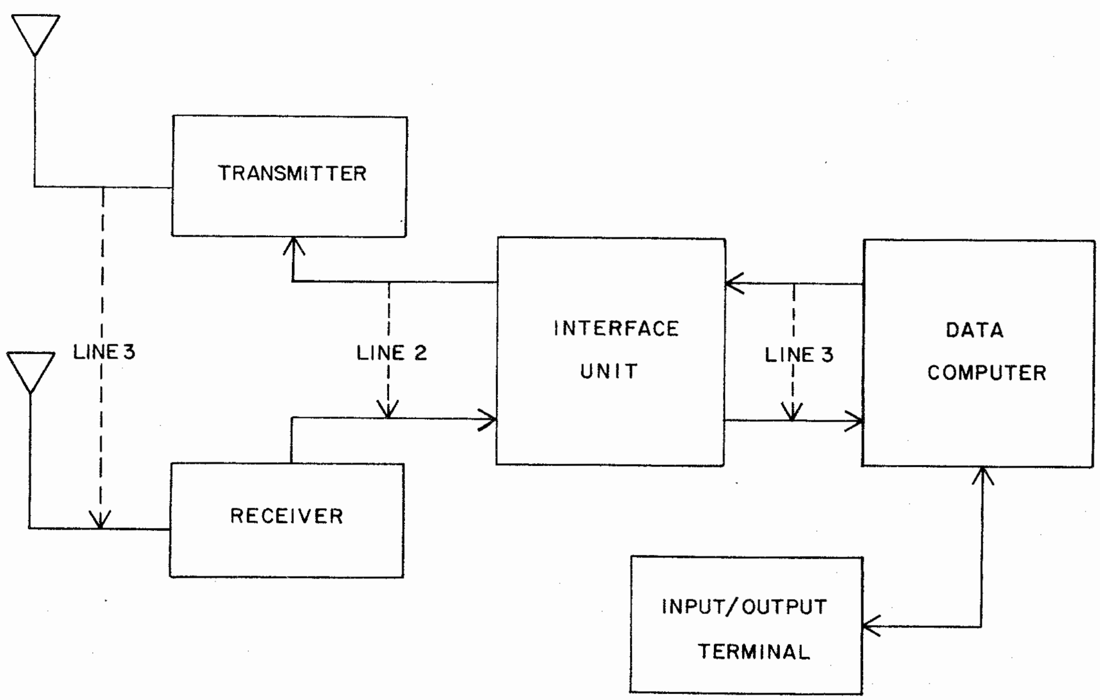


Figure 6-2. Typical "End Around" Test Configuration

This enables the ship to make any adjustments or repairs needed to ensure a satisfactorily functioning system. The off-ship testing station can either be a shore establishment set up specifically for this purpose, or it may be located on a designated ship or aircraft. However, before attempting to utilize an off-ship testing facility, the technician must employ all alternative means of ensuring his equipment is operating to specifications. The test facility can only evaluate a signal if it exists. Equipments being off frequency or putting out too little power can result in the signal's not being picked up by the off-ship testing facility.

6-4.4 INTERCONNECTING CABLE TESTING

The cables connecting system components together are also subject to fault generation within that system. Troubles could develop through loose or corroded connectors, grounded or shorted wires, and cold solder joints. In most instances, individual components of a system are located in such close proximity to each other that the standard ohmeter method for determining faulty connectors or wiring within a cable run is of doubtful value.

6-4.4.1 Cable-Short Testing

The procedure for determining if wires in a cable are shorted is to first disconnect both ends of the cable. An ohmeter is then used to measure each wire against another. In a multiconductor cable the quickest way to ensure that all wires are checked is to start with the least significant pin (e.g., 1 or A) and measure its resistance against the remaining pins in escalating order (i.e., 2, 3, 4, . . ./B, C, D, . . .). Then proceed to the next higher pin ("2" or "B") and measure its resistance against the remaining pins in escalating order (3, 4, 5, . . ./C, D, E, . . .). The process is continued until the entire cable has been checked out. Normally, a reading of infinity would be expected. Anything less would indicate a shorted wire or a partial short resulting from possible corrosion. Such wires must either be repaired or replaced. Similarly, a check for grounded wires would involve measuring the resistance of each wire in the cable to its shield. The same infinity reading is to be expected. Suspect wires that carry potentials in excess of 300V will require the use of a megger or Hi-pot tester instead of an ohmeter. This will ensure that the insulation of the wires does not break down under the high potential, thus shorting the wires when the normal high voltage of the current is applied.

6-4.4.2 Cable-Open Testing

Testing for open wiring in a cable is performed by connecting the wire under test between the open leads of an ohmeter. A reading of zero ohms is an indication of a satisfactory conductor. An infinity reading would indicate that the wire was broken (open). If an erratic reading is obtained, it may be due to a loose connection; however, if a high resistance reading is obtained, it could be the product of a cold solder connection, corrosion, or a loose connection. If anything other than the zero ohm reading is obtained, the cable must either be repaired or replaced. Some cable runs are of such length that placing the two ends directly across the open leads of an ohmeter is impractical. Two alternate methods can then be utilized. The first method entails shorting two wires in the cable together at one end, and then measuring the resistance at the other end. A zero reading should be obtained. If the entire cable is suspect, or if it is desired to eliminate any ambiguity, the wire under test could be grounded at one end. The open leads of the ohmeter would then be connected between the wire and ground to obtain the zero reading.

6-4.4.3 Fault Location in Long Cable Runs

Grounds, shorts and opens in long cable runs can be located by the bridge loop method. Each loop method utilizes a special arrangement of a Wheatstone bridge circuit and must satisfy bridge-balance conditions to obtain a correct reading. The bridge circuit is capable of measuring small resistances quite accurately, therefore certain types of faults in cable wires can be located by measuring the resistance of the wire, using special connections to the bridge circuit. The resistance value of the faulty wire between the fault and the bridge is then converted into distance to the fault by multiplying the value of the measured resistance by the feet-per-ohm factor for the proper wire size.

6-4.4.3.1 Ground Testing via Varley Loop

To locate a ground in a conductor, the suspect wire must first be joined at the far end to an ungrounded conductor, thus making a two-wire (Varley) loop. The resistance of this loop is then measured precisely, utilizing the bridge configuration illustrated in Figure 6-3A. The conductor known to be satisfactory is connected to X_1, and the grounded wire is connected to X_2. The bridge is then balanced by adjusting the A-B ratio control and the R control until the galvanometer indicates a midscale reading of zero. The value of "r" is then calculated from the relation;

$$r = \frac{A}{B} R$$

where: $\frac{A}{B}$ = setting of the ratio control

R = setting of the rheostat control

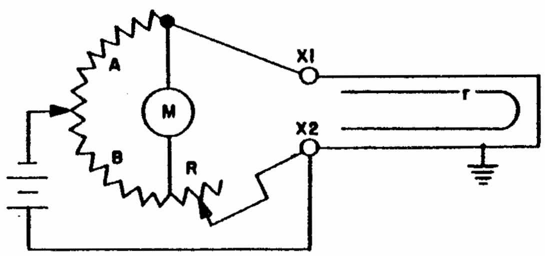
The loop is next connected to a good ground at conductor far end, as illustrated in Figure 6-3B. The bridge is again balanced by adjustment of the A-B and R controls and the readings are again noted. The resistance to ground is calculated by using the following formula:

$$X_a = \frac{rB - AR}{A + B}$$

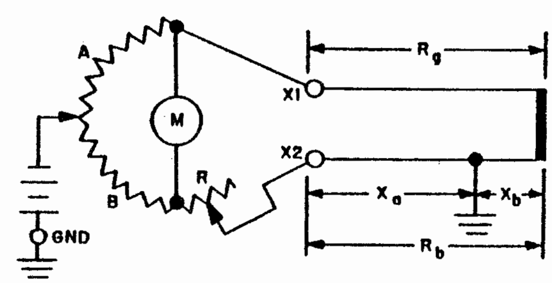
$$X_b = \frac{A(R + R_b) - BR_g}{A + B}$$

where:

- X_a = resistance of faulty wire, bridge to fault
- X_b = resistance of faulty wire, distant end to fault
- R = setting of rheostat arm
- r = total resistance of loop
- R_g = resistance of good wire used in test
- R_b = resistance of faulty wire used in test
- $\frac{A}{B}$ = setting of ratio



RESISTANCE MEASUREMENTS
(A)



VARLEY LOOP GROUND-LOCATION
(B)

Figure 6-3. Bridge Ground-Location Configuration

To convert X_a or X_b into distance to the fault, multiply the value of X_a or X_b by feet-per-ohm for the proper wire size.

6-4.4.3.2 Short (Cross) Testing via Varley Loop

To locate a short in a cable, one shorted conductor is connected to terminal X_2 of the bridge, and a good conductor is connected to terminal X_1 as illustrated in Figure 6-4. The distant ends of these two conductors are then joined together, and the shorted conductor is connected to the loop ground at the bridge end of the cable. The bridge is then balanced and the resistive values of the A-B and R control, along with the loop resistance value, are used in the formula of Paragraph 6-4.4.3.1. A simpler Varley Loop test for grounds and shorts can be employed provided both good and faulty conductors are of equal resistance. The connections for this test are the same as for the regular Varley Loop test method. The bridge is balanced with the R control after the A-B control is set for a ratio of 1:1. The resistance from the ground or short to the distant joined ends of the cable is obtained from the following formula:

$$X_b = \frac{R}{2}$$

where:

- X_b = resistance of faulty wire, from distant end to fault
- R = setting of rheostat arm

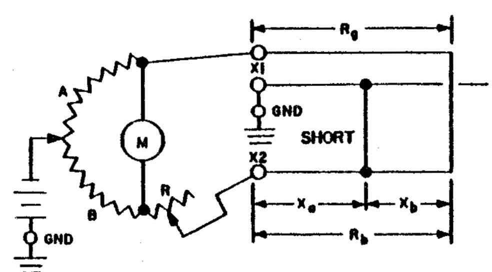
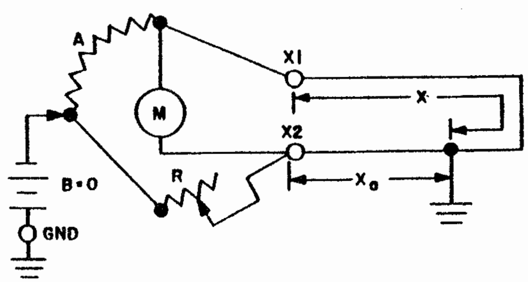


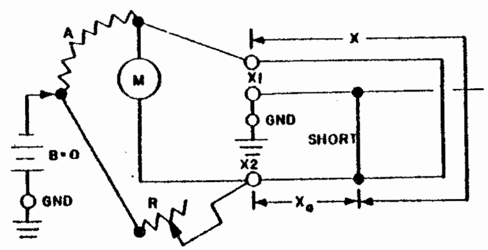
Figure 6-4. Bridge Short-Location Configuration

6-4.4.3.3 Alternative Loop Methods

Other loop methods that enable the technician to determine where a ground or a short exists in a cable include the Murray Loop method, illustrated in Figure 6-5A; the Hilborn Loop method, illustrated in Figure 6-5B; and the Three Varley method, illustrated in Figure 6-5C. The test procedure for all three is basically the same as for the Varley Loop method.



MURRAY LOOP GROUND LOCATION

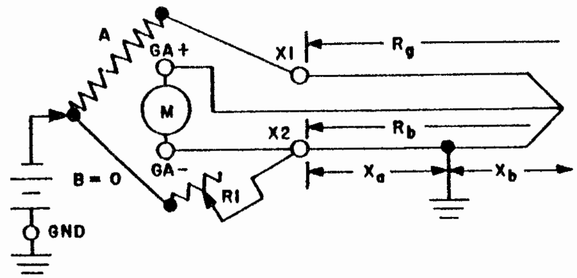


MURRAY LOOP SHORT LOCATION

$$X_a = \frac{R_r}{A + R}$$

where: X_a = resistance of faulty wire, bridge to fault
A = setting of ratio arm
R = setting of rheostat arm
r = total resistance R_r loop

A



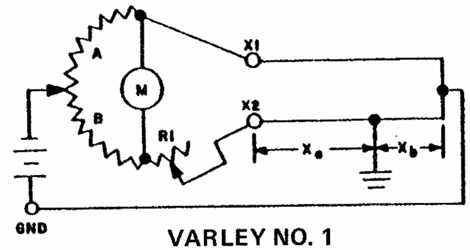
HILBORN LOOP TEST

$$X_b = \frac{A + R_g}{A + R_g + RI} R_b$$

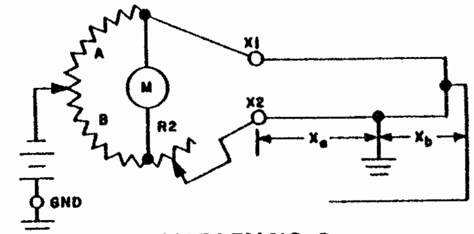
where: X_b = resistance of faulty wire, distant end to fault
A = setting of ratio arm
R_g = resistance of the good conductor
R_b = resistance of the faulty conductor

Note: Third conductor connected to GAT

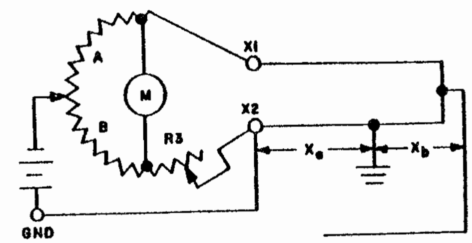
B



VARLEY NO. 1



VARLEY NO. 2



VARLEY NO. 3
THREE-VARLEY METHOD

$$X_b = \frac{A}{A + B} (R_3 - R_1)$$

$$X_a = \frac{A}{A + B} (R3 - R2)$$

where: R1, R2 and R3 = readings noted above
X_b = resistance of faulty wire, distant point to fault
X_a = resistance of faulty wire, bridge to fault

C

Figure 6-5. Three Alternate Bridge Loop Configurations

6-4.4.3.4 Opens Location via Bridge Method

Opens in multiconductor cables comprised of four or more conductors can be located by the four-conductor method. An audio signal generator and a headset are required for this test, in addition to a Wheatstone bridge. Figure 6-6 illustrates the configuration for this test. All conductors must be free of grounds and shorts prior to this test for opens. The

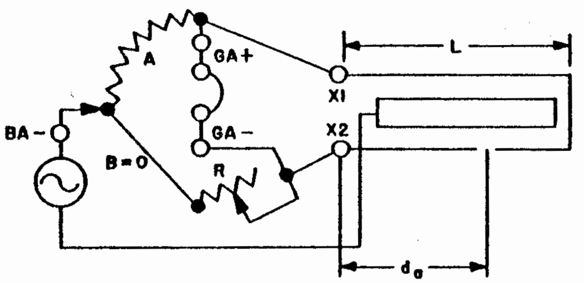


Figure 6-6. Open Location in Four-Conductor Cable

internal galvanometer of the Wheatstone bridge is disconnected and the headset is connected to terminals GA+ and GA- on the bridge. The open conductor is connected to terminal X_2, and a good conductor of equal gauge and length is connected to terminal X_1. These two conductors are then connected together at the distant end of the cable. The other two known good conductors of the cable are connected together at both ends, with the near end connected to one side of the audio signal generator. The other side of the generator is connected to the BA- terminal of the bridge. The bridge is then adjusted for minimum tone or silence in the headset. The control setting readings of A and R are used in the following formula to determine the resistance to open:

$$d_a = \frac{2LR}{A + B}$$

where:

d_a = distance from bridge to open, in feet
L = length of cable, in feet
A = setting of ratio arm
R = setting of rheostat arm

The test configuration for a two or more conductor cable is illustrated in Figure 6-7. In this configuration,

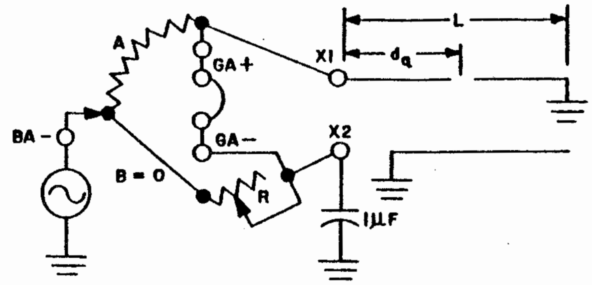


Figure 6-7. Opens Location in Two-Conductor Method

the open conductor is connected to terminal X_1 of the bridge and its distant end is grounded. The near end of one other conductor is also grounded, with its distant end open. A one-microfarad capacitor is connected between terminal X and ground. The audio signal is transmitted between terminal BA- of the bridge and ground. The bridge is then adjusted for minimum tone or silence in the headset. The value of A and R are then used in the formula:

$$d_a = \frac{AL}{A + R}$$

where:

d_a = distance from bridge to open, in feet
L = length of pair, in feet
A = setting of ratio arm
R = setting of rheostat arm

Thus, the procedure is the same as for that of the four-conductor method. Locating the distance to a short is obtained by multiplying the resistance obtained from formulas by the feet-per-ohm value of the proper gauge wire.

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