SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS4117

Issued 1991-03
Reaffirmed 2011-11

TEST PLAN FOR THE DIGITAL TIME DIVISION COMMAND/RESPONSE MULTIPLEX DATA BUS COUPLERS, TERMINATORS, AND DATA BUS CABLES

RATIONALE

This document has been reaffirmed to comply with the SAE 5-year Review policy.

FOREWORD

This test plan consists of three major sections. The first deals with testing data bus couplers, a second with testing data bus terminators, and a third section with testing of the data bus cable.

TABLE OF CONTENTS

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AS4117

TABLE OF CONTENTS (Continued)

1. SCOPE:

1.1 General:

This test plan defines the requirements of data bus components which comply with the requirements of MIL-STD-1553B, Digital Time Division Command/Response Multiplex Data Bus.

1.2 Application:

The requirements of the test plan shall apply to data bus components designed to meet MIL-STD-1553B, when invoked in a specification or a statement of work. The test plan may be used for both design verification and production testing of data bus components.

This test plan addresses only the electrical characteristics of the data bus components. Differences between data bus systems will exist due to particular program requirements and designer options. The system designer and contractor must therefore allow for the effects of temperature, vibration, sealing, EMI/EMP, and other environmental factors on data bus component characteristics. Consideration of these factors will improve the possibility that data bus components will operate properly when used in the intended environment.

The pass/fail requirements of the test plan shall be met under all system operating environments. The DC resistance criteria, however, are assumed to be measured at 25°C and would have to be corrected for measurements made at another temperature.

For the purposes of this test plan, it must be possible to identify all bus and stub connections, the selected bus cable characteristic impedance, the transformer winding resistances, and the values of any series and terminating resistors used within the coupler. This information must be included in a supporting documentation package provided by the bus coupler or bus terminator manufacturer.

Because transformer coupled data bus couplers may contain terminating resistors and/or have cables attached, it will not be possible to directly test the transformer and resistors in every case. In such cases the transformers and resistors shall be tested prior to assembly to verify they meet the requirements of MIL-STD-1553B. Again, system designers must make allowances for the expected environment when testing those coupler components.

1.2 (Continued):

Both connectorized and nonconnectorized couplers and terminators can be tested using this plan, provided electrical contact can be made to all signal (high and low) and shield (ground) connections of the components.

Multiple stub couplers are tested by repeating the tests contained herein for each individual stub. An adjustment to the test limits may be required. The adjustments are specified in the appropriate sections.

The tests may be performed in any order unless otherwise specified.

2. APPLICABLE DOCUMENTS:

2.1 Military Publications:

Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

MIL-STD-202F	Test Methods for Electronic and Electrical Component Parts
MIL-STD-1553B	Internal Time Division/Response Multiplex Data Bus, with Notice 2, 8 Sept. 1986

2.2 Definitions:

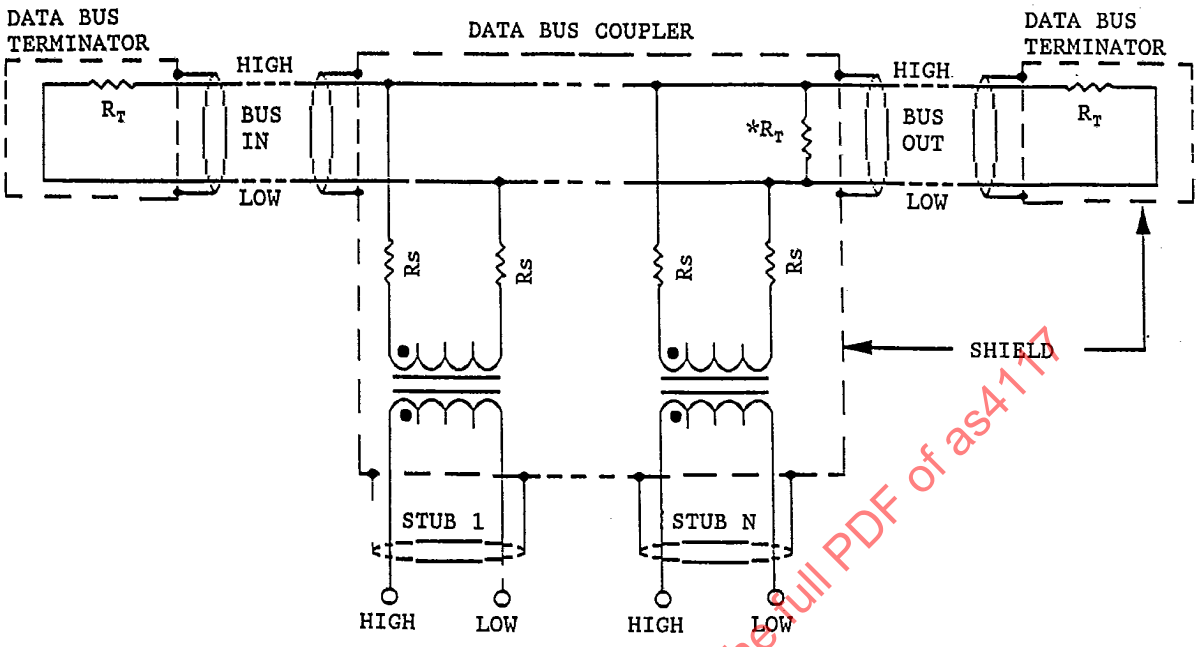
2.2.1 BUS CONNECTION(S): Connection(s) designated for attachment of the coupler to the bus cable. The test plan refers to them as bus in and bus out; each is functionally identical. Attachment may be in the form of connector(s) or cable leads. See Figure 1A or 1B.

2.2.2 STUB CONNECTION(S): Connection(s) designated for attachment of the stub cable to the coupler. The cable connection is made to a distinct transformer for a transformer coupled data bus coupler, while for a direct coupler, the connection is made directly to the bus. Attachment may be in the form of connector(s) or cable leads. See Figure 1A or 1B.

2.2.3 TERMINATORS: The shielded resistor used to terminate the bus in its characteristic impedance (Z_0).

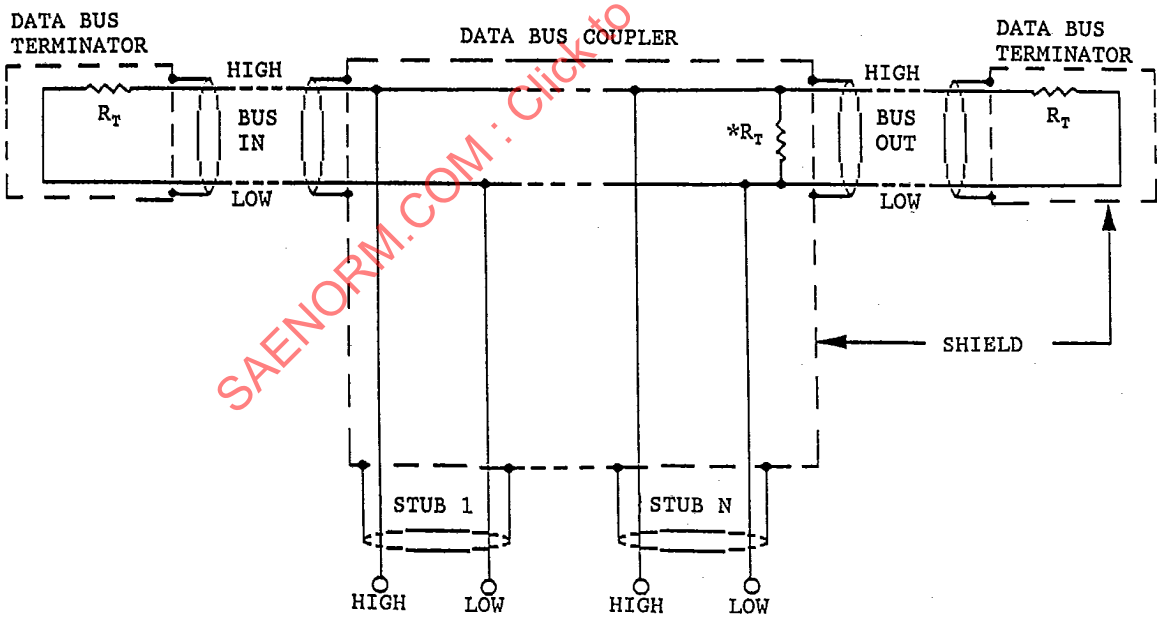
NOTE: The terminating resistor may be located inside the coupler. See Figure 1A or 1B.

2.2.4 SHIELD: The metallic enclosure which surrounds the coupler or terminator or the metallic braid surrounding the data bus cable. See Figure 1A or 1B.



*IF REQUIRED, THE TERMINATING RESISTOR COULD BE LOCATED INSIDE THE DATA BUS COUPLER.

FIGURE 1A - Transformer Data Bus Coupler



*IF REQUIRED, THE TERMINATING RESISTOR COULD BE LOCATED INSIDE THE DATA BUS COUPLER.

FIGURE 1B - Direct Data Bus Coupler

FIGURE 1 - Data Bus Couplers

2.2.5 DATA BUS COUPLER: It is the electronic module where the connection(s) between the stub(s) and the data bus are made. It consists of bus in and bus out connections and at least one stub connection. For transformer coupled applications, the stub connection is made using two isolation resistors and a coupling transformer per MIL-STD-1553B. A terminating resistor may be placed inside the coupler as shown in Figure 1A.

For direct coupled applications, the coupler consists of a shield in which a connection is made between the proper bus in and bus out signal leads to the corresponding stub signal leads. See Figure 1B.

NOTE: When an internal terminating resistor is used it is possible the coupler may have only one bus connection.

There are two basic styles of data bus coupler, one which has connectors and one which has cables attached. The type which has connectors is referred to in the test plan as "connectorized". The type with cables attached are referred to in the test plan as either in-line data bus couplers or cable-equipped data bus couplers.

2.2.6 DATA BUS CABLE: Two twisted, shielded, and jacketed conductors.

2.2.7 Z_o: The characteristic impedance of the data bus cable, where Characteristic Impedance =

$Z_o = \sqrt{(L/C_m)}$, with
L = Inductance per Foot
C_m = Mutual Capacitance per Foot

2.2.8 CABLE ATTENUATION: Cable power loss per unit length at a specified frequency, e.g., (db/100 ft at 1 MHz).

3. ELECTRICAL TESTS:

The following paragraphs define the configurations, pass/fail criteria, and general procedures for testing data bus couplers, terminators, and cables.

3.1 Data Bus Couplers:

The following four continuity tests shall be performed before attempting any other tests defined in this section.

3.1.1 Static Continuity Tests: The purpose of the following tests is to perform DC continuity and resistance measurements on the data bus couplers:

3.1.1.1 Bus Continuity Test (Bus In to Bus Out): Measure the resistance R, between bus in high and bus out high, as defined in Figure 1A or 1B. The pass criteria for a coupler with connectors attached shall be:

$$R = 0.050\ \Omega \text{ maximum} \qquad \text{(Eq.1)}$$

3.1.1.1 (Continued):

If the coupler is equipped with cables instead of connectors, a correction factor shall be applied to the above limit. For this case the pass criteria shall be:

$$R = (0.050 + R')\ \Omega \text{ maximum} \qquad \text{(Eq.2)}$$

where:

the correction factor R', is determined by multiplying the total cable length in feet L, by the DC resistance R_{dc}, per 1000 ft of the cable and adding it to the limit calculated for R.

$$R' = 0.001\ LR_{DC}\ \Omega \qquad \text{(Eq.3)}$$

This test shall be repeated for bus in low to bus out low.

NOTE: This test is not applicable to couplers that have only a bus in connection and an Internal terminating resistor.

3.1.1.2 Bus Continuity Test (Bus In High to Bus In Low):

3.1.1.2.1 Couplers With No Terminating Resistor: Measure the resistance R_B, between the high and low sides of either the bus in or bus out connections. The pass criteria shall be:

$$R_B = ((R_w + 2R_s)/N) \pm 3\%\ \Omega \qquad \text{(Eq.4)}$$

where:

R_w is the transformer bus winding resistance (assumed to be less than 5 Ω), R_s is the value of the bus isolation resistors, and N equals the number of stubs. The values for R_w and R_s are supplied by the manufacturer.

The pass/fail criteria applies to a specific coupler design and that the nominal value may change for different coupler types.

In the case of direct couplers, there shall be no continuity between signal high and low when measured on either bus in or bus out.

In cases where couplers have cable attached, the correction factor mentioned shall be required to allow for the additional resistance of the cable.

The modified pass criteria for R_B shall be:

$$R_B = (((R_w + 2R_s)/N) \pm 3\%) + R'\ \Omega \qquad \text{(Eq.5)}$$

where as defined in Equation 3:

$$R' = 0.001\ LR_{DC}\ \Omega \qquad \text{(Eq.3)}$$

3.1.1.2.2 Couplers With Internal Terminating Resistor: Measure the resistance R_B, between the high and low sides of the bus connection. The pass criteria shall be:

$$R_B = (((2R_S + R_W)R_t)/(2R_S + R_W + NR_t)) \pm 3\% \ \Omega \quad \text{(Eq.6)}$$

where:

R_s, R_w, and N are defined as before and R_t is the value of the terminating resistor, which shall be supplied by the coupler manufacturer.

This limit is for a specific coupler and will vary with the coupler design.

NOTE: For direct couplers R_B shall be equal to R_t.

In cases where couplers have cable attached, the correction factor mentioned shall be required to allow for the additional resistance of the cable. As before in Equation 3, the adjustment R', is equal to:

$$R' = 0.001 \ LR_{DC} \ \Omega \quad \text{(Eq.3)}$$

Therefore, the modified pass criteria for R_B shall be:

$$R_B = ((((2R_S + R_w)R_t)/(2R_S + R_W + NR_t)) \pm 3\%) + R' \ \Omega \quad \text{(Eq.7)}$$

3.1.1.3 Stub Continuity: Measure the resistance R_{st} of the high to low side of the stub connection. The pass criteria shall be:

$$R_{st} = 5.0 \ \Omega \text{ maximum} \quad \text{(Eq.8)}$$

When testing direct couplers without an internal terminating resistor, the value measured at the stub connection should be greater than 1 MΩ. If the direct coupler has an internal resistor R_t, the DC resistance value measured R_{int} shall be equal to:

$$R_{int} = R_t \pm 3\% \ \Omega \quad \text{(Eq.9)}$$

In transformer couplers, which have cables attached, the limits must be increased to reflect the additional DC resistance. The adjustment is determined as was shown. That amount is then added to the limit of 5 Ω for the transformer coupler or for a direct coupler the appropriate value of R_t. The pass criteria shall be:

$$R_{st} = (5 + R') \ \Omega \text{ maximum} \quad \text{(Eq.10)}$$

or in the case of a direct coupler with an internal resistor:

$$R_{int} = (R_t \pm 3\%) + R' \ \Omega \quad \text{(Eq.11)}$$

3.1.1.4 Shield Continuity: The DC resistance R_{shield} of the shield through the coupler shall be measured between each bus and stub shield connection point and the enclosure. For connectorized versions, the measurement points shall be the outer metal shell of the connector(s) and the mounting flange of the enclosure. The pass criteria shall be:

$$R_{shield} = 0.050\ \Omega \text{ maximum} \quad \text{(Eq.12)}$$

For couplers with cable attached, the measurement points shall be between each cable braid. The R_{shield} limit must be modified by the correction factor R', where R' is defined as before. The pass criteria shall be:

$$R_{shield} = (0.050 + R')\ \Omega \text{ maximum} \quad \text{(Eq.13)}$$

3.1.2 Dielectric Withstanding Voltage: The purpose of this test is to verify that there is adequate isolation provided between the shield and any signal lead.

When measured in accordance with MIL-STD-202F, at 600 V rms minimum and 50/60 Hz, with the potential applied between each bus signal lead and the shield for 1 min, the coupler under test shall show no evidence of breakdown or arcing.

The test shall be repeated with the potential applied between each stub signal lead and the shield.

3.1.3 Insulation Resistance: This test is used to quantitatively measure the resistance offered by the insulating materials of the coupler to an impressed direct voltage, which will tend to produce a leakage current through or on the surface of those materials.

3.1.3.1 Insulation Resistance (Signal Lead to Shield): When tested in accordance with MIL-STD-202F, at 250 V DC, with the potential applied between each bus signal lead and the shield, the coupler shall have an insulation resistance of 1000 MΩ minimum.

The test shall be repeated for each stub signal lead and the shield.

3.1.3.2 Insulation Resistance (Bus to Stub): When tested in accordance with MIL-STD-202F, at 250 V DC, with the potential applied between each stub signal lead and a bus signal lead, the coupler shall have an insulation resistance of 1000 MΩ minimum.

NOTE: This test is not applicable to direct couplers. If this test is applied to direct couplers, the couplers may be damaged.

3.1.4 MIL-STD-1553B Tests:

3.1.4.1 Waveform Integrity: This test is performed to verify that the data bus couplers meet the droop, overshoot, and ringing requirements of MIL-STD-1553B.

NOTE: For multiple stub or cable-equipped couplers, the transformers and resistors must be certified to comply with the requirements of MIL-STD-1553B as individual components.

A single stub coupler shall be tested using the configuration shown in Figure 2. A voltage of 27 V, peak-to-peak, shall be applied at point A using the waveform shown in Figure 3. The test frequency shall be equal to 250 kHz and the rise and fall time shall be set at 90 to 100 ns.

Droop, overshoot, and ringing shall be measured on the bus leads at point B.

The pass criteria for a single stub coupler shall be:

a. Waveform droop shall not exceed 20%, and overshoot and ringing measured on the bus side shall be less than ± 1 V peak as shown in Figure 4.

NOTE: This test is not applicable to direct couplers.

3.1.4.2 Impedance Z_o: The purpose of this test is to verify that the data bus couplers meet the requirements of MIL-STD-1553B for impedance.

When measured at frequencies of 75 kHz and 1 MHz with a 1 V rms sinewave signal applied to the bus side of the data bus coupler, the pass criteria shall be:

$$Z_o = 3000/N\ \Omega \text{ minimum} \qquad \text{(Eq.14)}$$

where:

N is equal to the number of stubs on the coupler.

For couplers which have cables attached or are internally terminated, the test shall be performed at a subassembly stage to verify this requirement. Impedance data shall be provided by the manufacturer to certify that the coupler meets the pass/fail criteria.

NOTE: This test is not applicable to direct couplers.

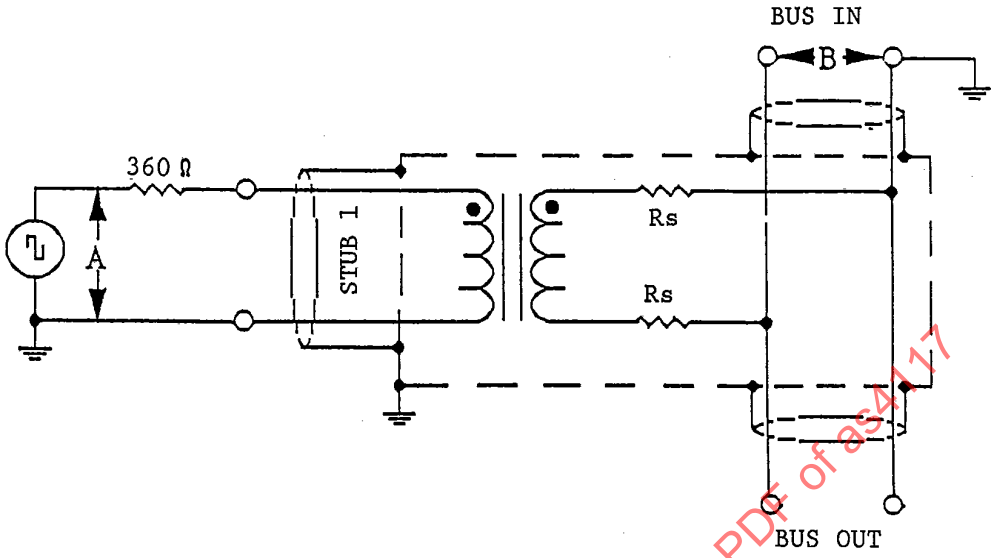


FIGURE 2 - Waveform Integrity Test Circuit

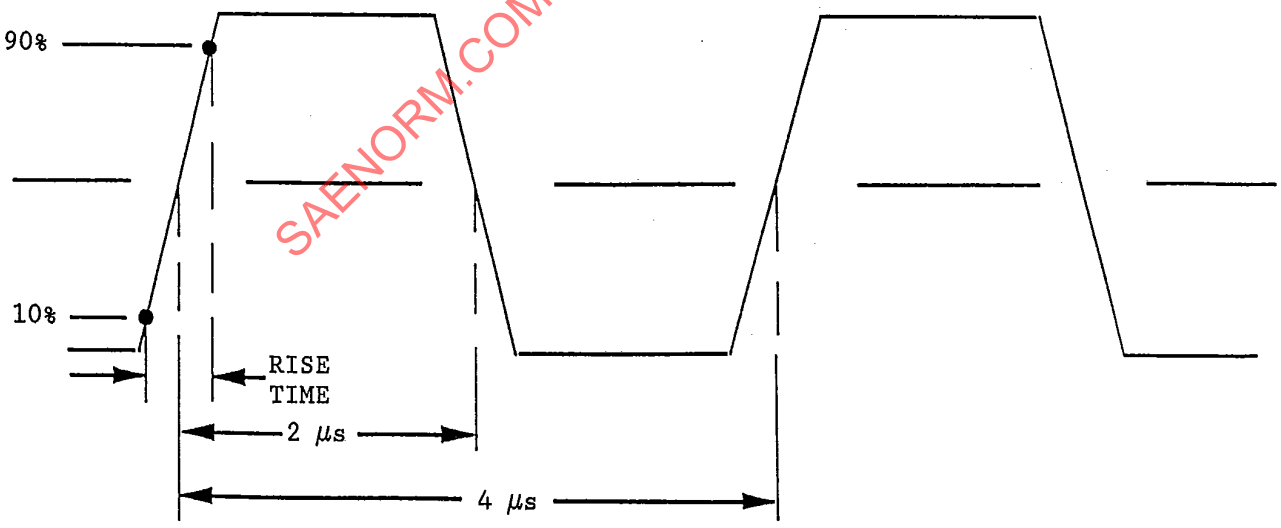


FIGURE 3 - Standard Input Waveform

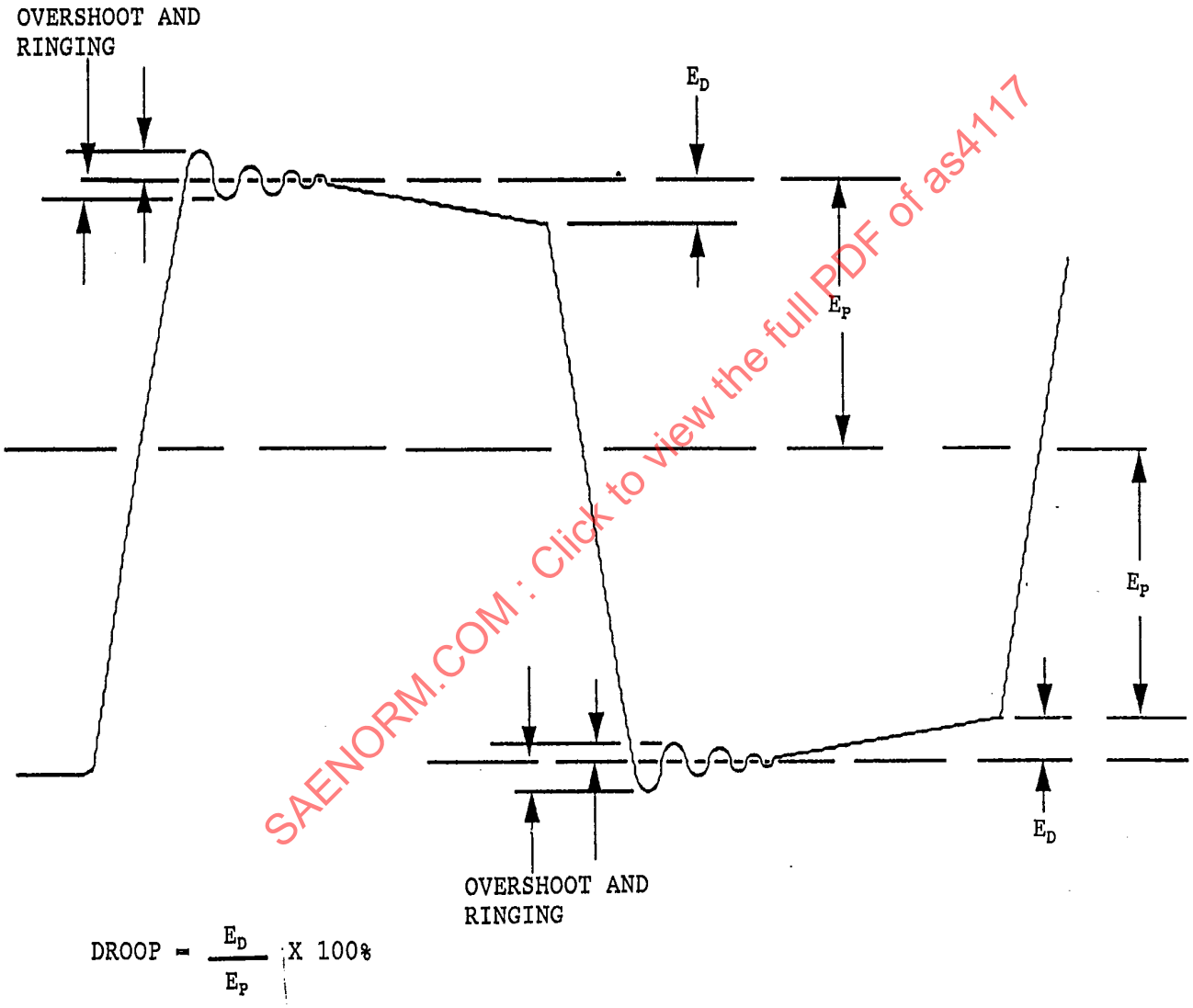


FIGURE 4 - Output Waveform

3.1.4.3 Common Mode Rejection: This test is performed to verify that data bus couplers meet MIL-STD-1553B requirements for common mode rejection (CMR). When tested in the circuit of Figure 5 at a frequency of 1 MHz, the CMR of the data bus couplers shall be:

$$CMR = 45 \text{ db minimum} \quad \text{(Eq.15)}$$

This limit applies to all stubs in a multiple stub coupler. The common mode rejection is determined from the following calculation where:

$$CMR(db)=20 \log (E_{in}/E_{out}) \quad \text{(Eq.16)}$$

where:

E_{out} and E_{in} are defined as in Figure 5.

NOTE: This test is not applicable to direct couplers.

3.1.5 Dynamic Electrical Tests: The following two tests verify that the data bus couplers provide signals with the proper amplitude and phase to the data bus network.

3.1.5.1 Coupler Bus Voltage Test: Use the circuit shown in Figure 6 for this test. Set the generator to provide an output conforming to the waveform defined by 4.5.2.1.1.1 and 4.5.2.1.1.2 of MIL-STD-1553B. Connect the generator directly to the coupler stub connection. Terminate both the bus in and bus out connections with terminators as defined in 2.2.3.

Measure the amplitude of the waveform at the stub connection. It shall be in the range of 18 to 27 V, peak-to-peak, line-to-line. Call this voltage V_{in}. The input risetime shall be set at 90 to 100 ns. Measure the amplitude of the waveform at the bus in or bus out connections. Call this voltage V_{out}. The pass criteria for bus in and bus out connections shall be:

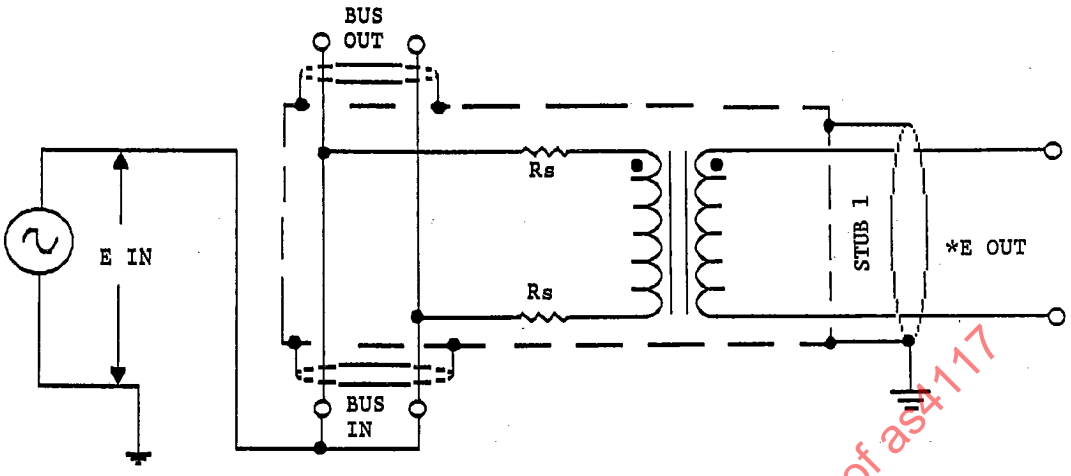
$$V_{out}/V_{in} = 0.331 \text{ to } 0.374 \quad \text{(Eq.17)}$$

NOTE: These values are determined using the worst case conditions for the transformers, isolation, and terminating resistors. The maximum value of V_{out}/V_{in} is for a transformer winding ratio of 1.41 + 3%, isolation resistor values of 0.75 Z_o - 2%, and terminating resistors of Z_o + 2%. The minimum value of V_{out}/V_{in} is for a winding ratio of 1.41 - 3%, isolation resistor values of 0.75 Z_o + 2%, and terminating resistor values of Z_o - 2%.

NOTE: If the coupler has an internal terminating resistor built in, it is necessary to only terminate either the bus in or bus out connection to perform the test.

Measure the rise and fall times of the waveform at the bus in or bus out connections. The pass criteria shall be:

$$\text{Rise or fall time} = 150 \text{ ns maximum} \quad \text{(Eq.18)}$$



NOTE: FOR SIMPLICITY, ONLY ONE STUB IS SHOWN.

E IN = 10 VRms
FREQUENCY = 1 MHz
*E OUT MEASURED DIFFERENTIALLY

FIGURE 5 - Common Mode Rejection Test Circuit

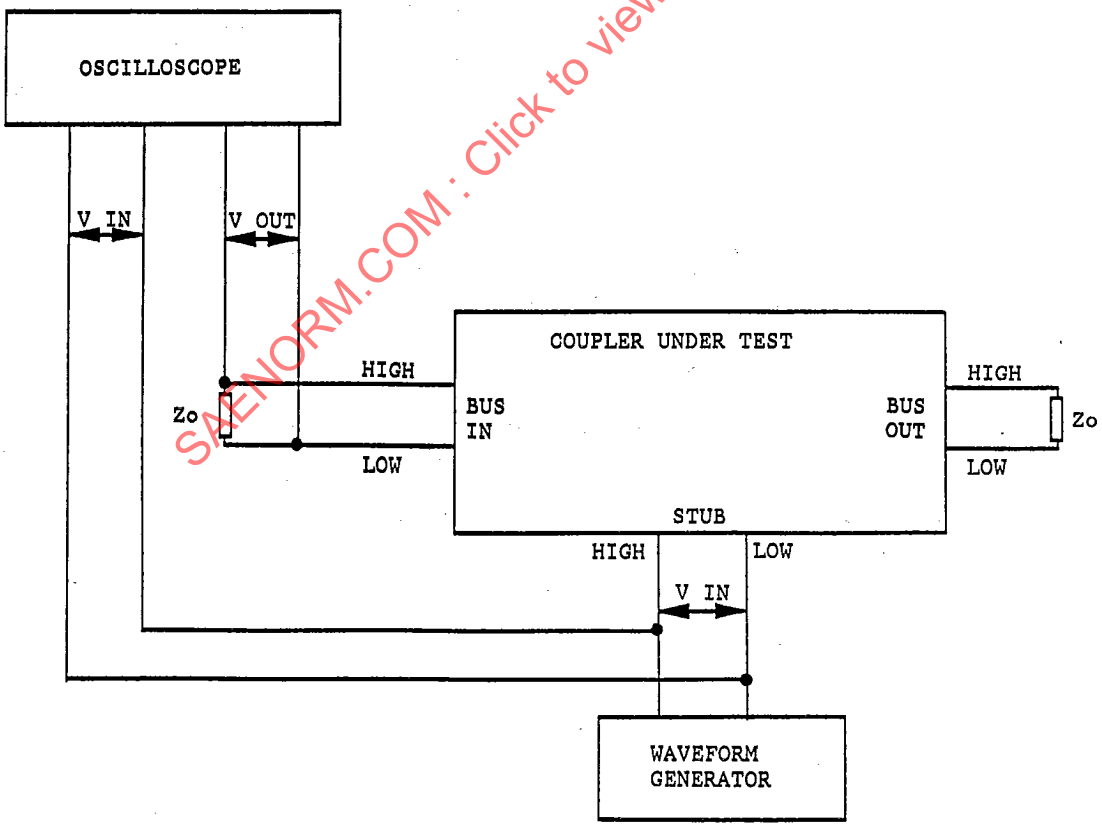


FIGURE 6 - Bus Voltage Test Circuit

3.1.5.1 (Continued):

NOTE: This limit applies only to couplers that have connectors attached. For cable-equipped couplers, rise and fall times may have to be determined before final assembly. Also, times are measured between the 10% and 90% points on the waveform. The test is not applicable to direct couplers.

3.1.5.2 Coupler Phasing and Amplitude Test: Use the test circuit of Figure 7 for this test.

Set the waveform generator to provide the output conforming to the waveform shown in Figure 3. Terminate the output of the waveform generator using a terminator as defined in 2.2.3.

Connect the terminated output to the bus in connection of the coupler under test. Terminate the bus out connection using a similar terminator unless there is an internal terminating resistor supplied within the coupler.

Measure the amplitude of the test waveform at the bus in connection of the coupler under test. It shall be in the range of 6 to 9 V, peak-to-peak, line-to-line. Call this voltage V_{in}.

Observe the phase relationship between the stub and bus voltages. The pass criteria shall be that the stub waveform shall be in phase with the bus in waveform.

NOTE: On multiple stub couplers, repeat this test using each stub.

After verifying the phase relationship, measure the amplitude of the waveform at the stub connection peak-to-peak, line-to-line. Call this voltage V_{out}. The pass criteria shall be:

$$V_{out}/V_{in} = 0.707 \pm 3\% \quad \text{(Eq.19)}$$

For direct couplers:

$$V_{out} = V_{in} \quad \text{(Eq.20)}$$

NOTE: For multiple stub couplers, repeat this test for each stub.

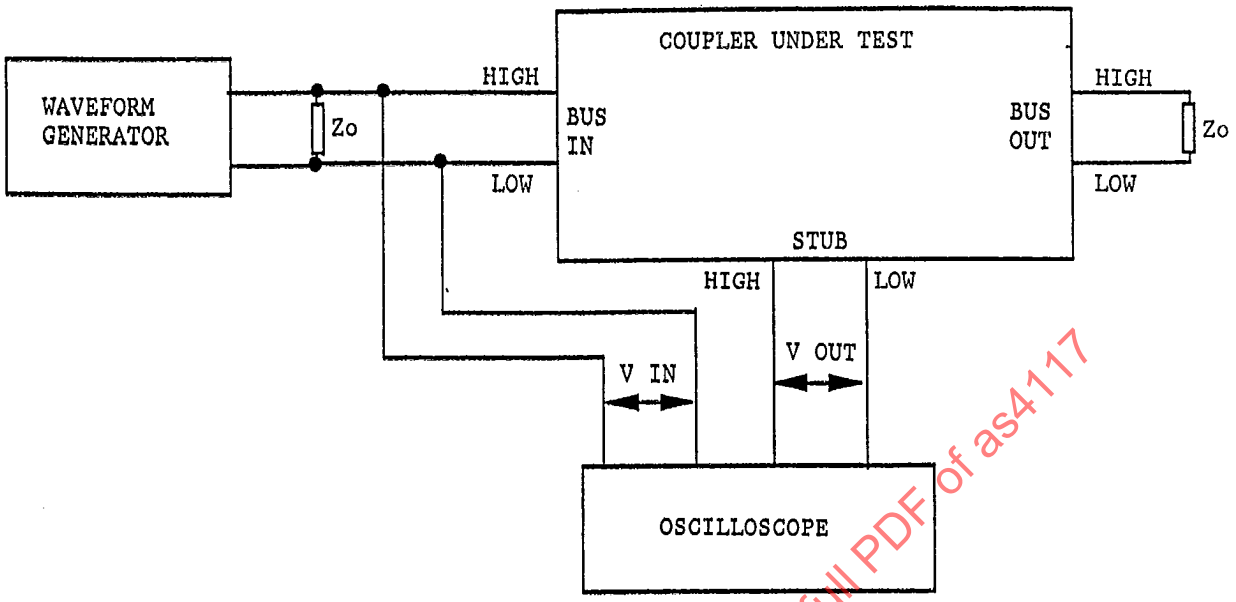


FIGURE 7 - Phasing and Amplitude Test Circuit

3.2 Data Bus Terminators:

The following tests apply to terminators supplied as a separate component.

3.2.1 Resistance Value: The purpose of this test is to verify that the terminator has the proper value of resistance based on the requirements of MIL-STD-1553B and the actual value of the characteristic impedance Z_o for the data bus cable selected. Measure the resistance R_t between signal leads of the data bus terminator. The pass criteria shall be:

$$R_t = Z_o \pm 2\% \ \Omega \qquad \text{(Eq.21)}$$

where:

Z_o is the nominal value provided by the manufacturer of the terminator.

NOTE: If the terminator has a cable attached:

$$R_t = (Z_o \pm 2\%) + R' \ \Omega \qquad \text{(Eq.22)}$$

where:

R' is defined in Equation 3.

3.2.2 Dielectric Withstanding Voltage: The purpose of this test is to verify that there is adequate isolation provided between the shield and either signal lead.

When measured in accordance with MIL-STD-202F at 600 V rms minimum and 50160 Hz with the potential applied between either signal lead and the shield for 1 min, the terminator under test shall exhibit no evidence of breakdown or arcing.

3.2.3 Insulation Resistance: This test is used to quantitatively measure the resistance offered by the insulating materials of the terminator to an impressed direct voltage, which will tend to produce a leakage current through or on the surface of these materials.

When tested in accordance with MIL-STD-202F at 250 V DC with the potential applied between either signal lead and the shield, the terminator shall have an insulation resistance of 1000 MΩ minimum.

3.3 Data Bus Cable:

3.3.1 Continuity: Electrical continuity testing shall be performed on all cable to verify that the conductors and shield(s) are continuous.

NOTE: This test should be performed prior to all other tests.

Apply a DC voltage to both ends of each conductor and shield of the cable through an appropriate continuity indicating device. The test voltage may be applied to the conductors and shield individually or in series:

NOTE: The cable shall have continuity throughout its length.

3.3.2 Conductor DC Resistance: This test shall verify that conductors within the completed cable are fabricated from the specified material and gauge. The test shall be repeated for each of the twisted pair conductors within the cable.

The cable test sample shall be free of splices, surface cracks, or other visible defects and shall be at least 36 inches in length. A rule shall be used to measure the length of the test sample to an accuracy of ±0.2%.

Resistance shall be measured with a Kelvin bridge, or a suitable four-terminal test method alternate if the resistance is below 1 Ω.

The resistance R_c shall be measured and recorded then converted to ohms per unit length. The temperature, conductor length, and conductor size shall be measured and recorded. The pass criteria shall be:

$$R_c = \text{nominal resistance value } +15\% \ \Omega \qquad \text{(Eq.23)}$$

NOTE: When the measurement is made at other than a reference temperature, the measured value must be corrected for the temperature difference, which exists between the actual measured resistance and the reference value.

3.3.3 Dielectric Withstanding Voltage: To ensure the integrity of the dielectric materials used in the fabrication of the cable, a dielectric withstanding test must be performed.