

MIL-STD-883E

METHOD 3001.1

DRIVE SOURCE, DYNAMIC

1. PURPOSE. This method establishes a drive source to be used in measuring dynamic performance of digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The drive source shall supply a smooth transition between specified voltage levels. The signal characteristics shall not vary outside of their prescribed tolerances when interfaced with the device under test (device in the test socket).

3. PROCEDURE. The drive source shall be measured at the input terminal of the test socket (no device in the test socket). Figure 3001-1 shows typical driving source waveforms and should be used specifying the parameters shown, unless otherwise stated in the applicable acquisition document.

3.1 Pulse amplitude. The specified HIGH level of the driving source shall be greater than the V_{OH} of the device. The specified LOW level of the driving source shall be less than V_{OL} of the device.

3.2 Transition times. The transition times of the driving source (t_{THL} and t_{TLH}) shall be faster than the transition time of the device being tested, unless otherwise stated in the acquisition document. The transition times shall normally be measured between the 10 percent and 90 percent levels of the specified pulse.

3.3 Pulse repetition rate (PRR). Unless the pulse repetition rate is the parameter being tested, it shall be chosen so that doubling the rate or reducing by a half will not affect the measurement results.

3.4 Duty factors (duty cycles). The duty cycles of the driving source shall be chosen so that a 10 percent variation in the duty cycle will not affect the measurement results. The duty cycle shall be defined with respect to either a positive or negative pulse. The pulse width (t_p) of the input pulses shall be measured between the specified input measurement levels. When more than one pulse input is needed to test a device, the duty cycle of the prime input (i.e., clock, etc.) shall be specified. The phase relationship of all other input pulses shall be referenced to the prime input pulse.

4. SUMMARY. The following details, when applicable, shall be specified in the applicable acquisition document:

- a. Levels V_{IL} and V_{IH} .
- b. Driving signal transition times.
- c. Pulse repetition rate.
- d. Duty factors.
- e. Recommended pulse generator, if required.
- f. Input measurement levels, if other than those shown in figure 3001-1.

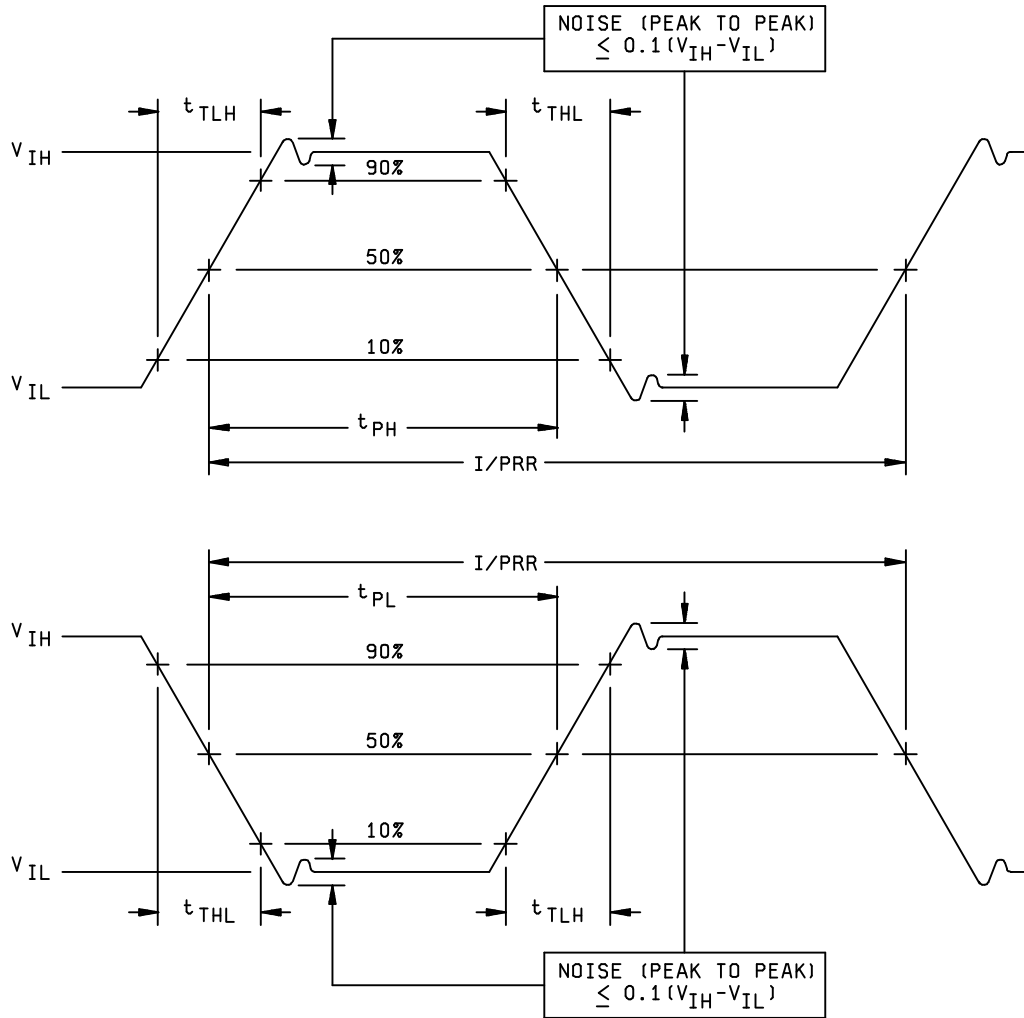


FIGURE 3001-1. Drive sources.

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METHOD 3002.1

LOAD CONDITIONS

1. PURPOSE. This method establishes the load conditions to be used in measuring the static and dynamic performance of digital microelectronic devices such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The load for static tests shall simulate the worst case conditions for the circuit parameters being tested. The load for dynamic tests shall simulate a specified use condition for the parameters being tested. The loads shall be specified in the applicable acquisition document.

2.1 Discrete component load. The load will consist of any combination of capacitive, inductive, resistive, or diode components.

2.1.1 Capacitive load (C_L). The total load capacitance of the circuit under test shall include probe and test fixture capacitance and a compensating capacitor as required. The value of the capacitance, measured at 1 MHz \pm 10 percent, shall be specified in the applicable acquisition document.

2.1.2 Inductive load (L_L). The total load inductance of the circuit under test shall include probe and test fixture inductance and a compensating inductor as required. The value of the inductance, measured at 1 MHz \pm 10 percent, shall be specified in the applicable acquisition document.

2.1.3 Resistive load (R_L). The resistive load shall represent the worst case fan out conditions of the device under test for static tests and a specified fan out condition for dynamic tests. For sink loads, the resistor shall be connected between the power supply (V_{CC} or V_{DD}) and the circuit output for TTL, DTL, RTL, C-MOS, and MOS (N-Channel) and between circuit output and ground for MOS (P-Channel). For source loads, the resistor shall be connected between circuit output and ground for TTL, DTL, RTL, C-MOS, and MOS (N-Channel) and between V_{DD} and the circuit output for MOS (P-Channel). For ECL devices, the load resistors are connected from the output to a specified negative voltage.

2.1.4 Diode load (D_L). The diode load shall represent the input diode(s) of the circuit under test. The equivalent diode, as specified in the applicable acquisition document, will also represent the base-emitter or base-collector diode of any transistor in the circuit path of the normal load.

2.2 Dynamic load change. The load shall automatically change its electrical parameters as the device under test changes logic state if this is the normal situation for the particular family of circuits being tested. One method of accomplishing this dynamic change is to simulate devices or use actual devices from the same logic family equal to the specified load.

3. PROCEDURE. The load will normally be paralleled by a high impedance voltage detection indicator. The indicator may be either visual or memory storage.

4. SUMMARY. The following shall be defined in the applicable acquisition document:

- a. Capacitive load (see 2.1.1).
- b. Inductive load (see 2.1.2).
- c. Resistive load (see 2.1.3).
- d. Diode load, the 1NXXX number and any associated critical parameters shall be specified (see 2.1.4).
- e. Negative voltage, when using a resistive load for ECL (see 2.1.3).

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METHOD 3003.1

DELAY MEASUREMENTS

1. PURPOSE. This method established the means for measuring propagation delay of digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

1.1 Definitions. The following definitions for the purpose of this test method shall apply.

1.1.1 Propagation delay time (t_{PHL}). The time measured with the specified output changing from the defined HIGH level to the defined LOW level with respect to the corresponding input transition.

1.1.2 Propagation delay time (t_{PLH}). The time measured with the specified output changing from the defined LOW level to the defined HIGH level with respect to the corresponding input transition.

2. APPARATUS. Equipment capable of measuring elapsed time between the input signal and output signal at any percentage point or voltage point between the maximum LOW level and minimum HIGH level shall be provided. The input shall be supplied by a driving source as described in method 3001 of this standard. It is desirable for this equipment to have data logging capability so that circuit dynamic performance can be monitored. The test chamber shall be capable of maintaining the device under test at any specified temperature.

3. PROCEDURE. The test circuit shall be loaded according to method 3002 of this standard. The driving signal to the test circuit shall be provided according to method 3001 of this standard. The device shall be stabilized at the specified test temperature.

3.1 Measurements at a voltage point. t_{PLH} and t_{PHL} shall be measured from the threshold voltage point on the driving signal to the threshold voltage point on the test circuit output signal for both inverting and noninverting logic. These delays shall be measured at the input and output terminals of the device under test. The device under test shall be conditioned according to the applicable acquisition document with nominal bias voltages applied. Figures 3003-1 and 3003-2 show typical delay measurements.

3.2 Measurements at percentage points. t_{PLH} and t_{PHL} shall be measured from a specified percentage point on the driving signal to a specified percentage point on the test circuit output signal for both inverting and noninverting logic. These delays shall be measured at the input and output terminals of the device under test. The device under test shall be conditioned according to the applicable acquisition document with nominal bias voltages applied. Figures 3003-1 and 3003-2 show typical delay measurements.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. t_{PLH} and t_{PHL} limits.
- b. Parameters of the driving signal: t_{THL} , t_{TLH} , high Level, low Level, pulse width, repetition rate.
- c. Load conditions.
- d. Conditioning voltages (static or dynamic).
- e. Measurement points (see 3.1 and 3.2).
- f. Power supply voltages.
- g. Test temperature.

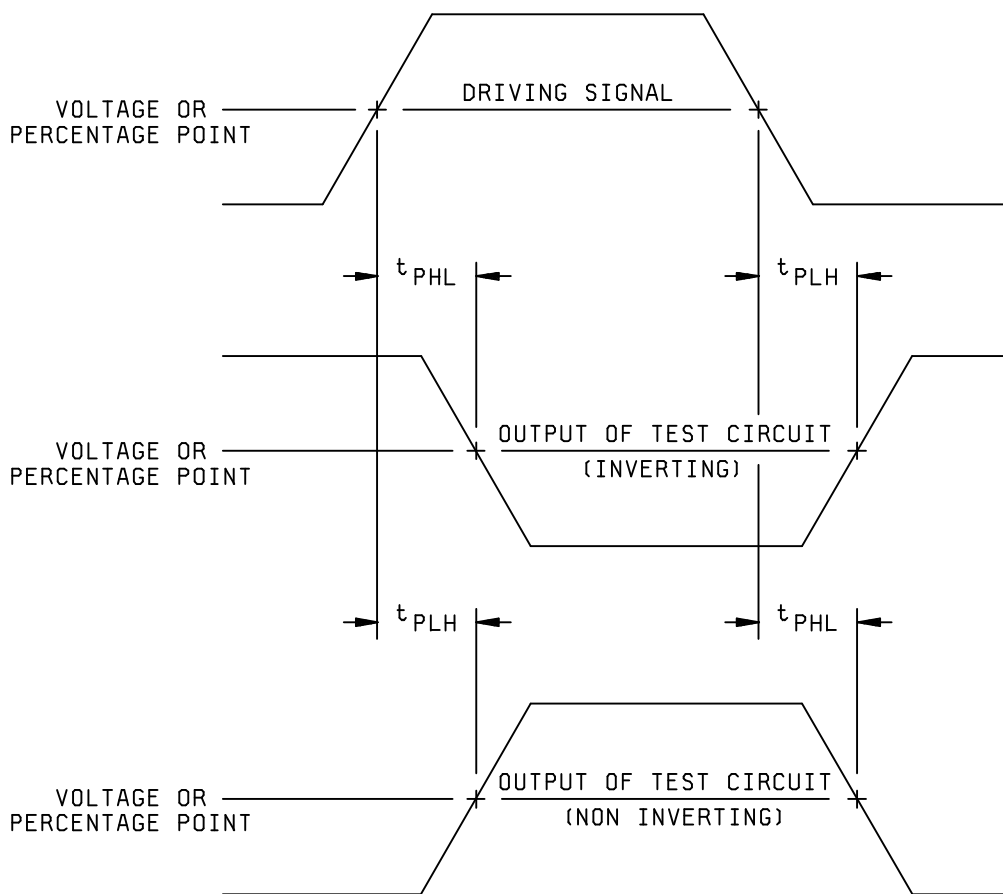


FIGURE 3003-1. Propagation delay-positive input pulse.

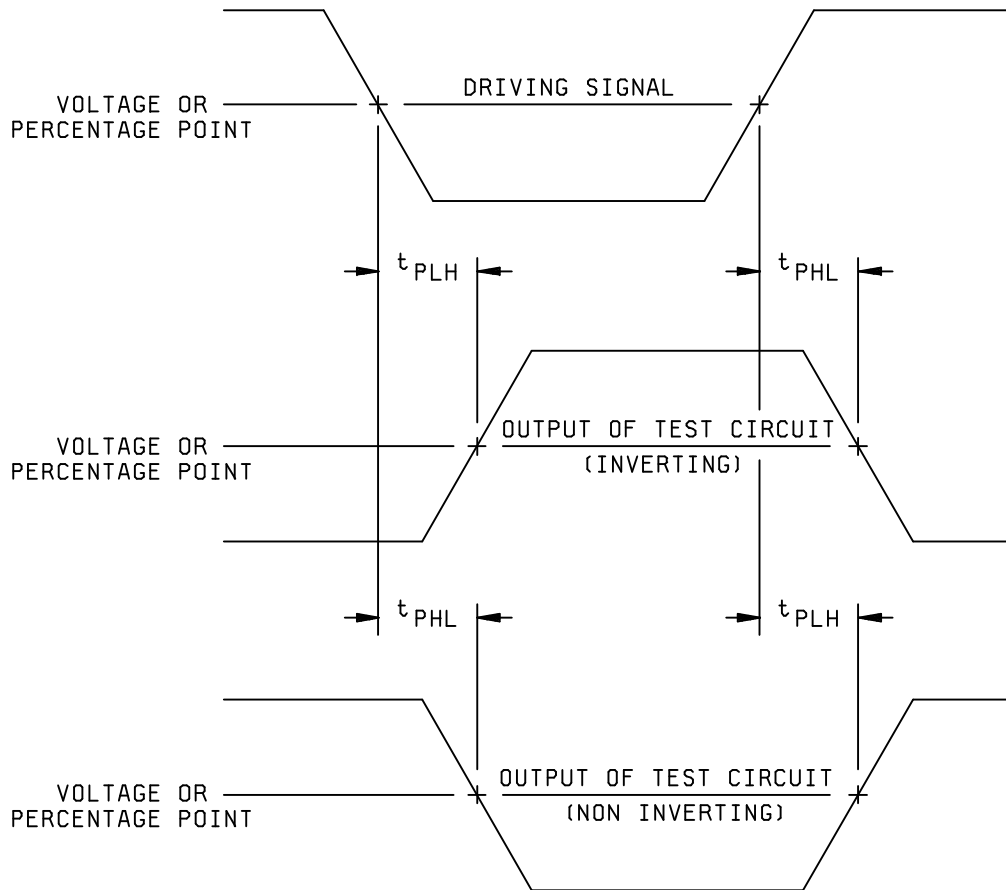


FIGURE 3003-2. Propagation delay - negative input pulse.

METHOD 3004.1

TRANSITION TIME MEASUREMENTS

1. PURPOSE. This method establishes the means for measuring the output transition times of digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

1.1 Definitions. The following definitions shall apply for the purpose of this method.

1.1.1 Rise time (t_{TLH}). The transition time of the output from 10 percent to 90 percent or voltage levels of output voltage with the specified output changing from the defined LOW level to the defined HIGH level.

1.1.2 Fall time (t_{THL}). The transition time of the output from 90 percent to 10 percent or voltage levels of output voltage with the specified output changing from the defined HIGH level to the defined LOW level.

2. APPARATUS. Equipment capable of measuring the elapsed time between specified percentage points (normally 10 percent to 90 percent on the positive transition and 90 percent to 10 percent on the negative transition) or voltage levels. The test chamber shall be capable of maintaining the device under test at any specified temperature.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. The device under test shall be loaded as specified in the applicable acquisition document. The load shall meet the requirements specified in method 3002 of this document. The driving signal shall be applied as specified in method 3001 or the applicable acquisition document.

3.1 Measurement of t_{TLH} and t_{THL} . Unless otherwise stated, the rise transition time (t_{TLH}) shall be measured between the 10 percent and 90 percent points on the positive transition of the output pulse and the fall transition time (t_{THL}) shall be measured between the 90 percent and 10 percent points on the negative transition of the output pulse. The device under test shall be conditioned according to the applicable acquisition document with nominal bias voltages applied. Figure 3004-1 shows typical transition time measurement.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. t_{TLH} limits.
- b. t_{THL} limits.
- c. Transition time measurement points if other than 10 percent or 90 percent.
- d. Parameters of the driving signal.
- e. Conditioning voltages (static or dynamic).
- f. Load condition.
- g. Power supply voltages.
- h. Test temperature.

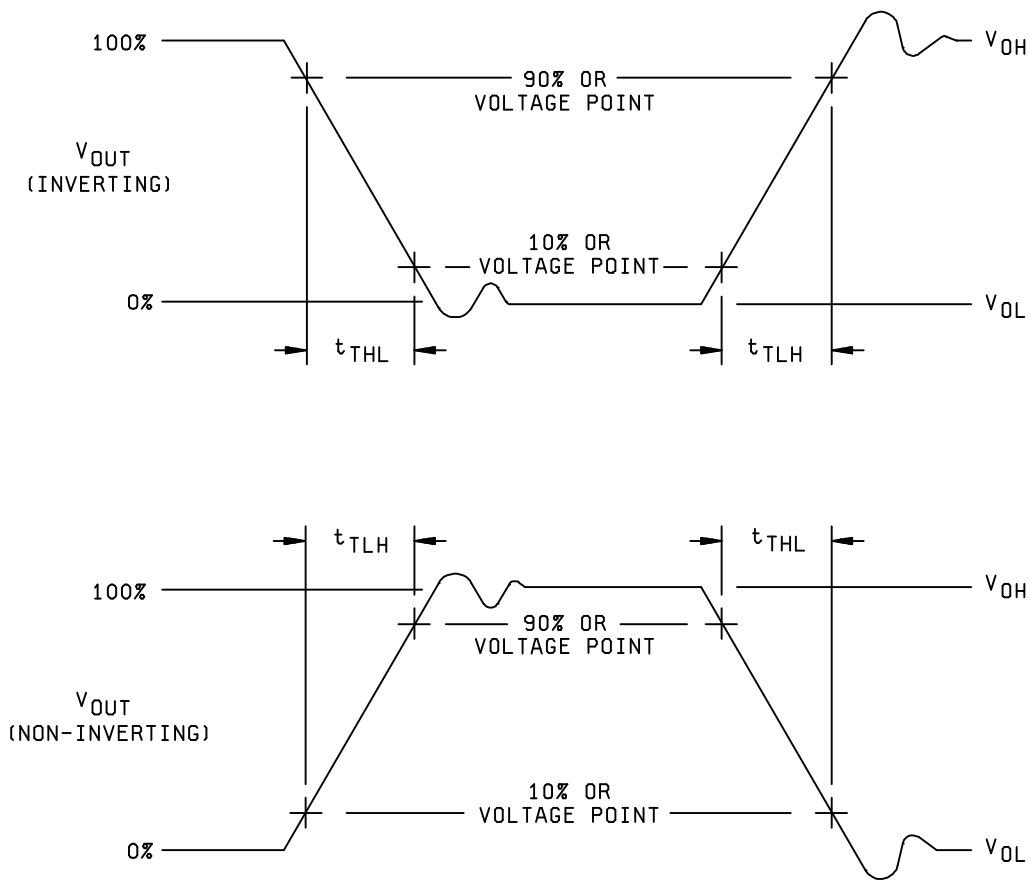


FIGURE 3004-1. Transition time measurements.

METHOD 3005.1

POWER SUPPLY CURRENT

1. PURPOSE. This method establishes the means for measuring power supply currents of digital microelectronic devices such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. Equipment capable of applying prescribed voltage to the test circuit power supply terminals and measuring the resultant currents flowing in these terminals shall be provided. The test chamber shall be capable of maintaining the device under test at any specified temperature.

3. PROCEDURE. The device shall be stabilized at the specified test temperature.

3.1 I_{CCH} (logic gate). Inputs of the device under test shall be conditioned in such a way as to provide a HIGH level at the output, the worst case supply voltage(s) shall be applied and the resultant current flow in the supply terminals measured.

3.2 I_{CCL} (logic gate). Inputs of the device under test shall be conditioned in such a way as to provide a LOW level at the output, the worst case supply voltages(s) shall be applied and the resultant current flow in the supply terminals measured.

3.3 I_{CC} or I_{EE} of combinatorial digital circuits. The inputs of the device under test shall be conditioned to put the device into its worst case power dissipating state. The current flowing into the V_{CC} , (positive supply) terminal, or out of the V_{EE} (negative supply) terminal shall be measured with the V_{CC} and V_{EE} voltages at their maximum specified operating levels.

3.4 I_{CC} or I_{EE} of sequential digital circuits. The inputs of the device under test shall be exercised to put the device in a known output state (either HIGH or LOW) that causes worst case power dissipation. The current flowing into the V_{CC} (positive supply) terminal, or out of the V_{EE} (negative supply) terminal shall be measured with the V_{CC} and V_{EE} voltages at their maximum specified operating levels.

3.5 I_{DD} (MOS logic gate). Inputs of the device under test shall be conditioned in such a way as to provide a HIGH level at the output of MOS (P-Channel and C-MOS) or a LOW level at the output of MOS (N-Channel and C-MOS); worst case voltage(s) shall be applied and the resultant current in the supply terminals measured.

3.6 I_{GG} (MOS P-Channel and N-Channel logic gates). Inputs of the device under test shall be conditioned in such a way as to provide a HIGH level at the output of MOS (P-Channel) or a LOW level at the output of MOS (N-Channel); worst case voltage(s) shall be applied and the resultant current flow in the supply terminals measured.

3.7 I_{DD} of MOS combinatorial circuits. See 3.3 above.

3.8 I_{DD} of MOS sequential circuits. See 3.4 above.

3.9 I_{GG} of MOS combinatorial circuits. See 3.3 above.

3.10 I_{GG} of MOS sequential circuits. See 3.4 above.

3.11 I_{DD} dynamic (MOS logic gating and flip flop circuits). The driving signal to the test circuit shall be provided according to method 3001 of this standard; the worst case voltage(s) shall be applied and the resultant average current in the supply terminals measured.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Power supply voltages.
- c. I_{CCH} , I_{CCL} , I_{DD} , I_{GG} , and I_{EE} limits.
- d. Conditioning voltages.
- e. Dynamic input parameters (see 3.11).

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METHOD 3006.1

HIGH LEVEL OUTPUT VOLTAGE

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to HIGH level output drive, which may be specified as a minimum value $V_{OH \text{ min.}}$ or as a maximum $V_{OH \text{ max.}}$. This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.
2. APPARATUS. The test instrument shall be capable of loading the output of the circuit under test with the specified positive or negative currents (I_{OH}). Resistors may be used to simulate the applicable current levels. The test instrument shall also be capable of supplying the worst case power supply and input voltages. The test chamber shall be capable of maintaining the device under test at any specified test temperature.
3. PROCEDURE. The device shall be stabilized at the specified test temperature. Worst case power supply voltages and worst case input levels including guaranteed noise margins shall be applied to the test circuit to provide a HIGH level output. Forcing current, equal to the circuit worst case high level fan out, shall then be applied to the test circuit output terminal and the resultant output voltage measured. The output measurement shall be made after each input is conditioned.
4. SUMMARY. The following details shall be specified in the applicable acquisition document:
 - a. Test temperature.
 - b. Current to be forced from or into output terminal.
 - c. Power supply voltage(s).
 - d. Input levels.
 - e. $V_{OH \text{ min.}}$ or $V_{OH \text{ max.}}$ limits.

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METHOD 3007.1

LOW LEVEL OUTPUT VOLTAGE

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document with regard to LOW level output drive which is specified as a maximum value ($V_{OL\ max}$) or a minimum value ($V_{OL\ min}$). This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The test instrument shall be capable of loading the output of the circuit under test with the specified positive or negative currents (I_{OL}). Resistors may be used to simulate the applicable current levels. The test instrument shall be capable of supplying the worst case power supply and input voltages. The test chamber shall be capable of maintaining the device under test at any specified temperature.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Worst case power supply voltages and worst case input levels including guaranteed noise margins shall be applied to the test circuit to provide a LOW level output. Forcing current, equal to the circuit worst case LOW level fan out, shall be applied to the test circuit output and the resultant output voltage measured. The output measurement shall be made after each input is conditioned.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Current to be forced into or from the output terminal.
- c. Power supply voltage(s).
- d. Input levels.
- e. $V_{OL\ max}$ or $V_{OL\ min}$ limits.

METHOD 3008.1

BREAKDOWN VOLTAGE, INPUT OR OUTPUT

1. PURPOSE. This method establishes the means for assuring device performance to the limits specified in the applicable acquisition document in regard to input and output breakdown voltage symbolized as V_{IH} (max), V_{OH} (max), V_{IL} (min), and V_{OL} (min) as applicable. This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified temperature.

2.1 Method A. This test is generally performed to assure that breakdown does not occur on a device. An instrument shall be provided that has the capability of forcing a specified voltage at the input or output terminal of the test circuit and measuring the resultant current flowing in that terminal. The test instrument shall also have the capability of applying voltage levels to all other terminals. Care should be taken to assure that the test equipment does not inadvertently apply voltage to the device under test that will exceed the maximum rating of each terminal and that the current from the test equipment is sufficiently limited so that the device is not destroyed. This method can also be used to test the ability of power supply terminals to withstand a voltage overload.

2.2 Method B. This test is generally performed to assure that breakdown does occur on a device as specified in the applicable acquisition document. An instrument shall be provided that has the capability of forcing a specified current at the input or output terminal of the test circuit and measuring the resultant voltage at that terminal. The test instrument shall also have the capability of applying voltage levels to all other terminals. Care should be taken to assure that the test equipment does not inadvertently apply voltage to the device under test that will exceed the maximum rating of each terminal so that the device is not destroyed. The minimum compliance voltage of the current source shall be specified when applicable.

3. PROCEDURE. The device shall be stabilized at the specified test temperature.

3.1 Method A. All terminals, with the exception of the test terminal, shall be conditioned according to the applicable acquisition document. A prescribed voltage shall be applied to the designated input or output terminal and the resultant current measured. When testing for breakdown, all input and output terminals shall be tested individually. At the conclusion of the test, the device shall be functional.

3.2 Method B. All terminals, with the exception of the test terminal, shall be conditioned according to the applicable acquisition document. The specified current shall be forced at the designated input or output terminal, and the voltage at the terminal measured. At the conclusion of the test, the device shall be functional.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Forced voltages (method A).
- c. Conditioning voltages for all other terminals.
- d. Forced current (method B).
- e. Maximum breakdown current limits (method A).
- f. Minimum breakdown terminal voltage (method B).

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METHOD 3009.1

INPUT CURRENT, LOW LEVEL

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to LOW level input load which may be specified as a minimum value (I_{IL} min) or as a maximum value (I_{IL} max). This method applied to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified test temperature. An instrument shall be provided that has the capability of applying the worst case LOW voltage to the input terminal of the test circuit, (and worst case levels on the other inputs), and measuring the resultant current at the input terminal.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Worst case power supply voltages and worst case input voltages shall be applied to the test circuit and the resultant current at the input terminal shall be measured. Inputs shall be tested individually.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Power supply voltages.
- c. Input voltage.
- d. Voltages at other input terminals which cause worst case current at the input under test.
- e. I_{IL} max or I_{IL} min.

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METHOD 3010.1

INPUT CURRENT, HIGH LEVEL

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to HIGH level input load which may be specified as a maximum value (I_{IH} max) or a minimum value (I_{IH} min). This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified temperature. An instrument shall be provided that has the capability of applying the worst case HIGH voltage to the input terminal of the test circuit, and worst case levels at the other inputs, and measuring the resultant current at the input terminal.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Worst case power supply voltages and worst case input voltages shall be applied to the test circuit and the resultant current at the input terminal shall be measured. Inputs shall be tested individually.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Power supply voltages.
- c. Input voltage.
- d. Input voltages at other input terminals which cause worst case current at the input under test.
- e. I_{IH} max.

METHOD 3011.1

OUTPUT SHORT CIRCUIT CURRENT

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to output short circuit current (I_{OS}). This method applied to digital microelectronic devices, such as TTL, DTL, RTL, and MOS.

2. APPARATUS. A test chamber capable of maintaining the device under test at any specified temperature. An instrument will be provided that has the capability of forcing a voltage specified in the applicable acquisition document at the output terminal of the device under test and measuring the resultant current flowing in that terminal. The test instrument shall also have the capability of applying specified voltage levels to all other inputs.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Each output per package shall be tested individually.

3.1 TTL, DTL, RTL, MOS (P-Channel and N-Channel). Inputs of the device under test shall be conditioned in such a way as to provide a HIGH level at the output for TTL, DTL, RTL, and MOS (N-Channel) and a LOW level at the output for MOS (P-Channel). The output terminal shall be forced to 0 volt potential and the resultant current flow measured.

3.2 C-MOS I_{OSH} . Inputs of the device under test shall be conditioned in such a way as to provide a HIGH level at the output. The output terminal shall be forced to 0 volt potential and the resultant current flow measured.

3.3 C-MOS I_{OSL} . Inputs of the device under test shall be conditioned in such a way as to provide a LOW level at the output. The output terminal shall be forced to a voltage potential specified in the acquisition document and the resultant current flow measured.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Input conditioning voltages.
- c. Power supply voltages.
- d. I_{OS} max and I_{OS} min limits.

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METHOD 3012.1

TERMINAL CAPACITANCE

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to terminal capacitance. This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. The instrument shall be capable of applying a 1 MHz controllable amplitude signal superimposed on a variable plus or minus dc voltage. The instrument will also have the capability of measuring the capacitance of this terminal to within the limits and tolerance specified in the applicable acquisition document.

3. PROCEDURE. This test may be performed at $25^{\circ}\text{C} \pm 3^{\circ}\text{C}$. The capacitance measuring bridge shall be connected between the input or output terminal and the ground terminal of the test circuit. The bridge shall be adjusted for a signal of 1 MHz, riding a bias level specified in the applicable acquisition document; the signal amplitude shall not exceed 50 mV rms. With no device in the test socket the bridge shall then be zeroed. For capacitance values below 20 pF, the device shall be connected directly to the bridge with leads as short as possible to avoid the effects of lead inductance. After inserting the device under test and applying the specified bias conditions, the terminal capacitance shall be measured and compared to the limits listed in the applicable acquisition document.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Circuit bias conditions.
- b. Bias level at which measurements are to be made.
- c. Maximum capacitance limits.

METHOD 3013.1

NOISE MARGIN MEASUREMENTS FOR DIGITAL MICROELECTRONIC DEVICES

1. PURPOSE. This method establishes the means of measuring the dc (steady- state) and ac (transient) noise margin of digital microelectronic devices or to determine compliance with specified noise margin requirements in the applicable acquisition document. It is also intended to provide assurance of interchangeability of devices and to eliminate misunderstanding between manufacturers and users on noise margin test procedures and results. The standardization of particular combinations of test parameters (e.g., pulse width, pulse amplitude, etc.) does not preclude the characterization of devices under test with other variations in these parameters. However, such variations shall, where applicable, be provided as additional conditions of test and shall not serve as a substitute for the requirements established herein.

1.1 Definitions. The following definitions shall apply for the purposes of this test method:

- a. Noise margin. Noise margin is defined as the voltage amplitude of extraneous signal which can be algebraically added to the noise-free worst case "input" level before the output voltage deviates from the allowable logic voltage levels. The term "input" (in quotation marks) is used here to refer to logic input terminals or ground reference terminals.
- b. DC noise margin. DC noise margin is defined as the dc voltage amplitude which can be algebraically added to the noise-free worst case "input" level before the output exceeds the allowable logic voltage levels.
- c. AC noise margin. AC noise margin is defined as the transient or pulse voltage amplitude which can be algebraically added to the noise-free worst case "input" level before the output voltage exceeds the allowable logic voltage levels.
- d. Maximum and minimum. Maximum and minimum refer to an algebraic system where "max" represents the most positive value of the range and "min" represents the least positive value of the range.

1.2 Symbols. The following symbols shall apply for the purposes of this test method and shall be used in accordance with the definitions provided (see 1.2.1, 1.2.2, and 1.2.3) and depicted on figures 3013-1, 3013-2, and 3013-3.

1.2.1 Logic levels.

V_{IL} max: The maximum allowed input LOW level in a logic system.

V_{IL} min: The minimum allowed input LOW level in a logic system.

V_{IH} max: The maximum allowed input HIGH level in a logic system.

V_{IH} min: The minimum allowed input HIGH level in a logic system.

V_{OL} max: The maximum output LOW level specified for a digital microelectronic device.
 V_{OL} max is also the noise-free worst case input LOW level, $V_{OL} (\text{max}) \leq V_{IL} (\text{max})$

V_{OH} min: The minimum output HIGH level specified for a digital microelectronic device.
 V_{OH} min is also the noise-free worst case input HIGH level, $V_{OH} (\text{min}) \geq V_{IH} (\text{min})$

Noise margin levels.

V_{NL} : The LOW level noise margin or input voltage amplitude which can be algebraically added to $V_{OL} (\text{max})$ before the output level exceeds the allowed logic level.

V_{NH} : The HIGH level noise margin or input voltage amplitude which can be algebraically added to $V_{OH} (\text{min})$ before the output level exceeds the allowed logic level.

V_{NG+} : The positive voltage which can be algebraically added to the ground level before the output exceeds the allowed logic level determined by worst case logic input levels.

- V_{NG} .: The negative voltage which can be algebraically added to the ground level before the output exceeds the allowed logic level determined by worst case logic input levels.
- V_{NP+} .: The positive voltage which can be algebraically added to the noise-free worst case most positive power supply voltage before the output exceeds the allowed logic level determined by worst case logic input levels.
- V_{NP-} .: The negative voltage which can be algebraically added to the noise-free worst case most negative (least positive) power supply voltage before the output exceeds the allowed logic level determined by worst case logic input levels.

1.2.3 Noise pulse widths.

- t_{PL} .: The LOW level noise pulse width, measured at the V_{IL} (max) level.
- t_{PH} .: The HIGH level noise pulse width, measured at the V_{IH} (min) level.

2. APPARATUS. The apparatus used for noise margin measurements shall include a suitable source generator (see 2.1), load (see 2.2), and voltage detection devices for determining logic state.

2.1 Source generator. The source generator for this test shall be capable of supplying the required ac and dc noise inputs. In the case of pulsed inputs the transition times of the injected noise pulse shall each be maintained to less than 20 percent of the pulse width measured at the 50 percent amplitude level. For the purpose of this criteria, the transition times shall be between the 10 percent and 90 percent amplitude levels. The pulse repetition rate shall be sufficiently low that the element under test is at steady-state conditions prior to application of the noise pulse. For the purpose of this criteria, doubling the repetition rate or duty cycle shall not affect the outcome of the measurement.

2.2 Load. The load for this test shall simulate the circuit parameters of the normal load which would be applied in application of the device under worst-case conditions. The load shall automatically change its electrical parameters as the device under test changes logic state if this is the normal situation for the particular device load. The load shall be paralleled by a high impedance voltage detection device.

3. PROCEDURE. The device shall be connected for operation using a source generator and load as specified (see 2), and measurements shall be made of V_{NL} , V_{NH} , V_{NG} , V_{NP} , t_{PL} , and t_{PH} following the procedures for both ac noise margin and dc noise margin (see 3.2 through 3.3.3).

3.1 General considerations.

3.1.1 Nonpropagation of injected noise. As defined in 1.1, noise margin is the amplitude of extraneous signal which may be added to a noise-free worst case "input" level before the output breaks the allowable logic levels. This definition of noise margin allows the measurement of both dc and ac noise immunity on logic inputs or power supply lines or ground reference lines by detection of either a maximum LOW level or a minimum HIGH level at the output terminal. Since the output level never exceeds the allowable logic level under conditions of injected noise, the noise is not considered to propagate through the element under test.

3.1.2 Superposition of simultaneously injected noise. Because the logic levels are restored after one stage, and because the noise margin measurement is performed with all "inactive" inputs at the worst case logic levels, the proper system logic levels are guaranteed in the presence of simultaneous disturbances separated by at least one stage.

3.1.3 Characterization of ac noise margin. Although the purpose of this standard test procedure is to insure interchangeability of elements by a single- point measurement of ac noise margin, the test procedure is well suited to the measurement of ac noise margin as a function of noise pulse width. In particular, for very wide pulse widths, the ac noise margin asymptotes to a value identically equal to the dc noise margin.

3.2 Test procedure for dc noise margin.

3.2.1 Worse case configuration. The measurement of dc noise margin using a particular logic input terminal should correspond to the worst case test configuration in the applicable acquisition document. For example, the measurement of LOW level noise margin for a positive-logic inverting NAND gate should be performed under the same worst case test conditions as the dc measurement of V_{OH} (min). If the worst case dc test conditions for V_{OH} (min) are high power supply voltage, all unused logic inputs connected to V_{OH} (min) and output current equal to zero, these conditions should be applied to the corresponding dc noise margin measurement.

3.2.2 LOW level noise margin, V_{NL} . The LOW level noise margin test is normally performed during the V_{OH} test for inverting logic and during the V_{OL} test for noninverting logic. The noise margin is calculated from the following expression:

$$V_{NL} = V_{IL} (\text{max}) - V_{OL} (\text{max})$$

3.2.3 HIGH level noise margin, V_{NH} . The HIGH level noise margin test is performed during the V_{OL} test for inverting logic and during the V_{OH} test for noninverting logic. The noise margin is calculated from the following expression:

$$V_{NH} = V_{OH} (\text{min}) - V_{IH} (\text{min})$$

3.2.4 Negative ground noise margin, V_{NG} . With all power supply and output terminals connected to the appropriate worst case conditions, apply V_{OL} (max) to the inputs specified in the applicable acquisition document and decrease the voltage applied to the ground terminal until the output levels equal V_{IH} (min) for inverting logic and V_{IL} (max) for noninverting logic. The dc ground noise margin is the voltage measured at the device ground terminal. The dc source resistance of the injected ground line voltage shall be negligible.

3.2.5 Positive ground noise margin, V_{NG+} . With all power supply and output terminals connected to the appropriate worst case conditions, apply V_{OH} (min) to the inputs specified in the applicable acquisition document and increase the voltage applied to the ground terminal until the output levels equal V_{IL} (max) for inverting logic and V_{IH} (min) for noninverting logic. The dc ground noise margin is the voltage measured at the device ground terminal. The dc source resistance of the injected ground line voltage shall be negligible.

3.2.6 Power supply noise margin, V_{NP+} or V_{NP-} . With all input, power supply, and output terminals connected to the appropriate worst case conditions, increase (or decrease) the power supply voltage(s) until the output level equals the appropriate logic level limit. The power supply noise margin is the difference between the measured supply voltage(s) and the appropriate noise-free worst case supply voltage level(s). If more than one power supply is required, the noise margin of each supply should be measured separately.

3.3 Test procedure for ac noise margin.

3.3.1 AC noise margin test point. If, for any combination of noise pulse width or transition times, the ac noise margin is less than the dc noise margin, the noise pulse amplitude, pulse width, and transition time which produce the minimum noise margin shall be used as the conditions for test. If the ac noise margin exceeds the dc noise margin, the dc noise margin tests only shall be performed.

3.3.2 LOW level noise margin, pulse width, T_{PL} . With all unused logic input, power supply, and output terminals connected to the appropriate worst case conditions, a positive-going noise pulse shall be applied to the input under test. The pulse amplitude shall be equal to V_{OH} (min) minus V_{OL} (max); the pulse amplitude shall be equal to V_{OH} (max); and the transition times shall be much less than the minimum transition times of the device under test. The test is performed by initially adjusting the input pulse width at the 0.9 amplitude level to one and one quarter times the rise time. The pulse width is increased until the output voltage is equal to V_{IH} (max) for inverting logic and equal to V_{IL} (min) for noninverting logic. The noise margin pulse width is then measured at the input pulse V_{IL} (max) level.

3.3.3 HIGH level noise margin, pulse width, T_{PH} . With all unused logic input, power supply, and output terminals connected to the appropriate worst case conditions, a negative-going noise pulse shall be applied to the input under test. The pulse amplitude shall be equal to V_{OH} (min) minus V_{OL} (max); the pulse shall be superimposed on a dc level equal to V_{OH} (min); and the transition times shall be much less than the minimum transition times of the device under test. The test is performed by initially adjusting the input pulse width at the 0.1 amplitude level to one and one quarter times the rise time. The pulse width is increased until the output voltage is equal to V_{IL} (min) for inverting logic and V_{IH} (max) for noninverting logic. The noise margin pulse width is then measured at the input pulse V_{IH} (min) level.

4. SUMMARY. The following details, when applicable, shall be specified in the applicable acquisition document:

- a. V_{IL} (max).
- b. V_{IL} (min).
- c. V_{IH} (min).
- d. V_{IH} (max).
- e. V_{OL} (max).
- f. V_{OH} (min).
- g. V_{NL} .
- h. V_{NH} .
- i. V_{NG} .
- j. V_{NP} .
- k. t_{PL} .
- l. t_{PH} .
- m. Test temperature. Unless otherwise specified, dc noise margin measurements shall be made at the rated operating temperature extremes in addition to any other nominal test temperatures.
- n. Specific noise margin measurements and conditions which are to be performed.
- o. Power supply voltages.
- p. Input conditioning voltages.
- q. Output loads.
- r. Parameters of noise signal.

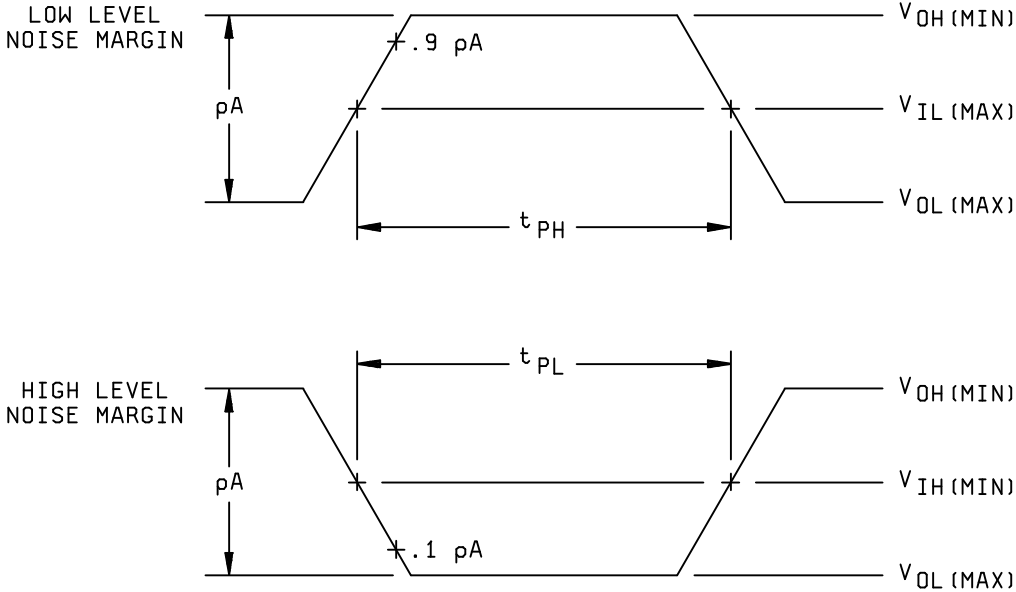


FIGURE 3013-1. Definitions of noise pulse width.

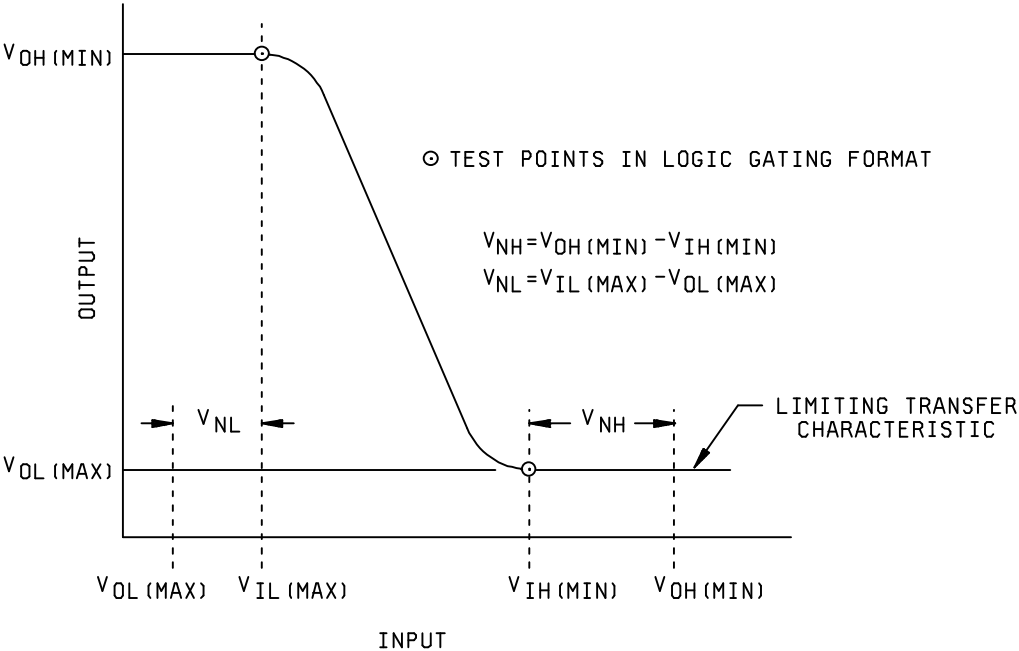


FIGURE 3013-2. Inverting logic gate transfer characteristic defining test points.

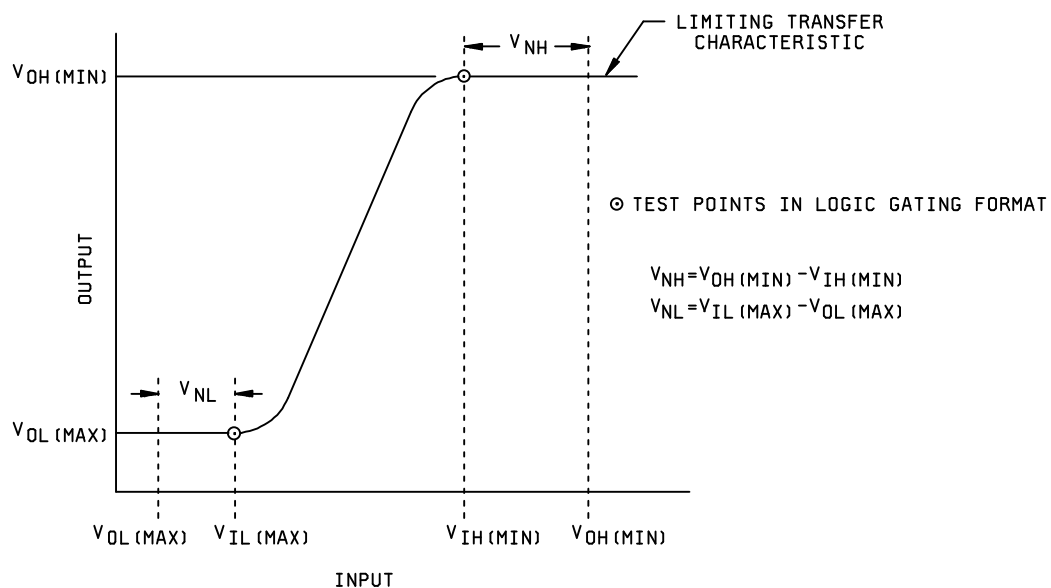


FIGURE 3013-3. Noninverting logic gate transfer characteristic defining test points.

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METHOD 3014

FUNCTIONAL TESTING

1. PURPOSE. This method establishes the means for assuring circuit performance in regard to the test requirements necessary to verify the specified function and to assure that all logic element paths are not open, stuck-at-HIGH level or stuck-at-LOW LEVEL. This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS.

2. APPARATUS. An instrument shall be provided which has the capability of applying logic patterns (sequentially, if specified) to the logic network input(s) in accordance with the applicable acquisition document. The test instrument shall also be capable of applying nominal power supply voltages and monitoring the outputs for the specified logic levels. The output monitoring circuit may be either a single or double comparator type. The threshold voltage (trip point) for a single comparator or V_{OL} (max) and V_{OH} (min) for a double comparator shall be specified in the applicable acquisition document. The test chamber shall be capable of maintaining the device under test at any specified test temperature.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Nominal power supply voltages and the specified input logic patterns shall be applied to the logic network under test and the output(s) monitored.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Power supply voltage.
- c. Input voltage levels.
- d. Input and output logic patterns.
- e. Output threshold voltage (see 2).
- f. V_{OH} (min) and V_{OL} (max) (see 2).

METHOD 3015.7

ELECTROSTATIC DISCHARGE SENSITIVITY CLASSIFICATION

* 1. PURPOSE. This method establishes the procedure for classifying microcircuits according to their susceptibility to damage or degradation by exposure to electrostatic discharge (ESD). This classification is used to specify appropriate packaging and handling requirements in accordance with MIL-PRF--38535, and to provide classification data to meet the requirements of MIL-STD-1686.

1.1 Definition. The following definition shall apply for the purposes of this test method.

1.1.1 Electrostatic discharge (ESD). A transfer of electrostatic charge between two bodies at different electrostatic potentials.

2. APPARATUS.

2.1 Test apparatus. ESD pulse simulator and device under test (DUT) socket equivalent to the circuit of figure 3015-1, and capable of supplying pulses with the characteristics required by figure 3015-2.

2.2 Measurement equipment. Equipment including an oscilloscope and current probe to verify conformance of the simulator output pulse to the requirements of figure 3015-2.

2.2.1 Oscilloscope and amplifier. The oscilloscope and amplifier combination shall have a 350 MHz minimum bandwidth and a visual writing speed of 4 cm/ns minimum.

2.2.2 Current probe. The current probe shall have a minimum bandwidth of 350 MHz (e.g., Tektronix CT-1 at 1,000 MHz).

2.2.3 Charging voltage probe. The charging voltage probe shall have a minimum input resistance of 1,000 MΩ and a division ratio of 4 percent maximum (e.g., HP 34111A).

2.3 Calibration. Periodic calibration shall include but not be limited to the following.

2.3.1 Charging voltage. The meter used to display the simulator charging voltage shall be calibrated to indicate the actual voltage at points C and D of figure 3015-1, over the range specified in table I.

2.3.2 Effective capacitance. Effective capacitance shall be determined by charging C1 to the specified voltage (with table I), with no device in the test socket and the test switch open, and by discharging C1 into an electrometer, coulombmeter, or calibrated capacitor connected between points A and B of figure 3015-1. The effective capacitance shall be 100 pF ±10 percent over the specified voltage range and shall be periodically verified at 1,000 volts. (Note: A series resistor may be needed to slow the discharge and obtain a valid measurement.)

2.3.3 Current waveform. The procedure of 3.2 shall be performed for each voltage step of table I. The current waveform at each step shall meet the requirements of figure 3015-2.

2.4 Qualification. Apparatus acceptance tests shall be performed on new equipment or after major repair. Testing shall include but not be limited to the following.

2.4.1 Current waveform verification. Current waveform shall be verified at every pin of each test fixture using the pin nearest terminal B (see figure 3015-1) as the reference point. All waveforms shall meet the requirements of figure 3015-2. The pin pair representing the worst case (closest to the limits) waveform shall be identified and used for the verification required by 3.2.

3. PROCEDURE.

3.1 General.

3.1.1 Test circuit. Classification testing shall be performed using a test circuit equivalent to figure 3015-1 to produce the waveform shown on figure 3015-2.

3.1.2 Test temperature. Each device shall be stabilized at room temperature prior to and during testing.

3.1.3 ESD classification testing. ESD classification testing of devices shall be considered destructive.

3.2 ESD simulator current waveform verification. To ensure proper simulator operation, the current waveform verification procedure shall be done, as a minimum, at the beginning of each shift when ESD testing is performed, or prior to testing after each change of the socket/board, whichever is sooner. If the simulator does not meet all requirements, all classification testing done since the last successful verification shall be repeated. At the time of initial facility certification and recertifications, photographs shall be taken of the waveforms observed as required by 3.2c through 3.2e and be kept on file for purposes of audit and comparison. (Stored digitized representations of the waveforms are acceptable in place of photographs.)

- a. With the DUT socket installed on the simulator, and with no DUT in the socket, place a short (figure 3015-1) across two pins of the DUT socket and connect one of the pins to simulator terminal A and the other pin to terminal B.
- b. Connect the current probe around the short near terminal B (see figure 3015-1). Set the simulator charging voltage source V_S to 4,000 volts corresponding to step 4 of table I.
- c. Initiate a simulator pulse and observe the leading edge of the current waveform. The current waveform shall meet the rise time, peak current, and ringing requirements of figure 3015-2.
- d. Initiate a simulator pulse again and observe the complete current waveform. The pulse shall meet the decay time and ringing requirement of figure 3015-2.
- e. Repeat the above verification procedure using the opposite polarity ($V_S = -4,000$ volts).
- f. It is recommended that the simulator output be checked to verify that there is only one pulse per initiation, and that there is no pulse while capacitor C1 is being charged. To observe the recharge transient, set the trigger to the opposite polarity, increase the vertical sensitivity by approximately a factor of 10, and initiate a pulse.

TABLE I. Simulator charging voltage (V_S) steps versus peak current (I_P). 1/

Step	V_S (volts)	I_P (amperes)
1	500	0.33
2	1,000	0.67
3	2,000	1.33
4	4,000	2.67

1/ I_P is the current flowing through R2 during the current waveform verification procedure and which is approximately $V_S/1,500$ ohms.

3.3 Classification testing.

- a. A sample of devices (see 4.c) shall be characterized for the device ESD failure threshold using the voltage steps shown in table I, as a minimum. Finer voltage steps may optionally be used to obtain a more accurate measure of the failure voltage. Testing may begin at any voltage step, except for devices which have demonstrated healing effects, including those with spark gap protection, which shall be started at the lowest step. Examination of known technology family input or output V/I damage characteristics (i.e., curve tracer), or other simplified test verification techniques may be used to validate the failure threshold (e.g., cumulative damage effects may be eliminated by retesting at the failure voltage step using a new sample of devices and possibly passing the step).

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- b. A new sample of devices shall be selected and subjected to the next lower voltage step used. Each device shall be tested using three positive and three negative pulses using each of the pin combinations shown in table II. A minimum of 1 second delay shall separate the pulses.
- c. The sample devices shall be electrically tested to subgroups 1 and 7 as applicable (room temperature dc parameters and functional tests).
- d. If one or more of the devices fail, the testing of 3.3b and 3.3c shall be repeated at the next lower voltage step used.
- e. If none of the devices fail, record the failure threshold determined in 3.3a. Note the highest step passed, and use it to classify the device according to table III.

TABLE II. Pin combinations to be tested. 1/ 2/

	Terminal A (Each pin individually connected to terminal A with the other floating)	Terminal B (The common combination of all like-named pins connected to terminal B)
1.	All pins except V_{ps1} 3/	All V_{ps1} pins
2.	All input and output pins	All other input-output pins

1/ Table II is restated in narrative form in 3.4 below.

2/ No connects are not to be tested.

3/ Repeat pin combination 1 for each named power supply and for ground (e.g., where V_{ps1} is V_{DD} , V_{CC} , V_{SS} , V_{BB} , GND, $+V_S$, $-V_S$, V_{REF} , etc.)

3.4 Pin combination to be tested.

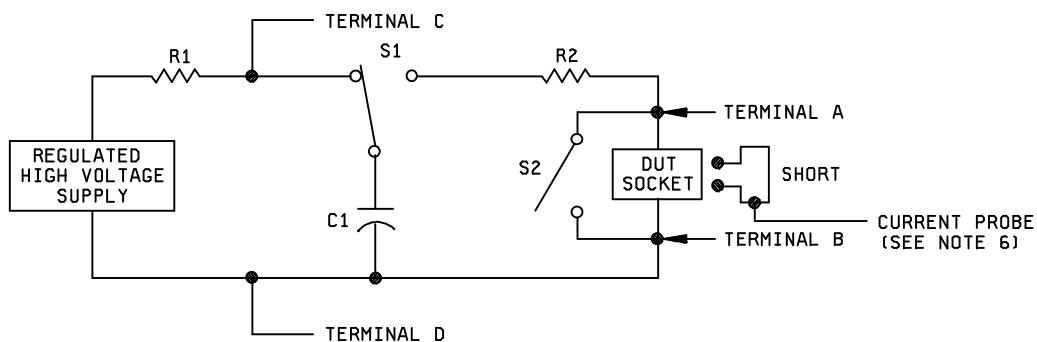
- a. Each pin individually connected to terminal A with respect to the device ground pin(s) connected to terminal B. All pins except the one being tested and the ground pin(s) shall be open.
- b. Each pin individually connected to terminal A with respect to each different set of a combination of all named power supply pins (e.g., V_{SS1} or V_{SS2} or V_{SS3} or V_{CC1} or V_{CC2}) connected to terminal B. All pins except the one being tested and the power supply pin or set of pins shall be open.
- c. Each input and each output individually connected to terminal A with respect to a combination of all the other input and output pins connected to terminal B. All pins except the input or output pin being tested and the combination of all the other input and output pins shall be open.

TABLE III. Device ESD failure threshold classification.

Class 1	0 volt to 1,999 volts
Class 2	2,000 volts to 3,999 volts
Class 3	4,000 volts and above

4. SUMMARY. The following details shall be specified in the applicable purchase order or contract, if other than specified herein.

- a. Post test electricals.
- b. Special additional or substitute pin combinations, if applicable.
- c. Sample size, if other than three devices.



$R1 = 10^6$ ohms to 10^7 ohms
 $C1 = 100$ picofarads ± 10 percent
 $R2 = 1,500$ ohms ± 1 percent
 $S1 =$ High voltage relay
 $S2 =$ Normally closed switch

(Insulation resistance 10^{12} ohms minimum)

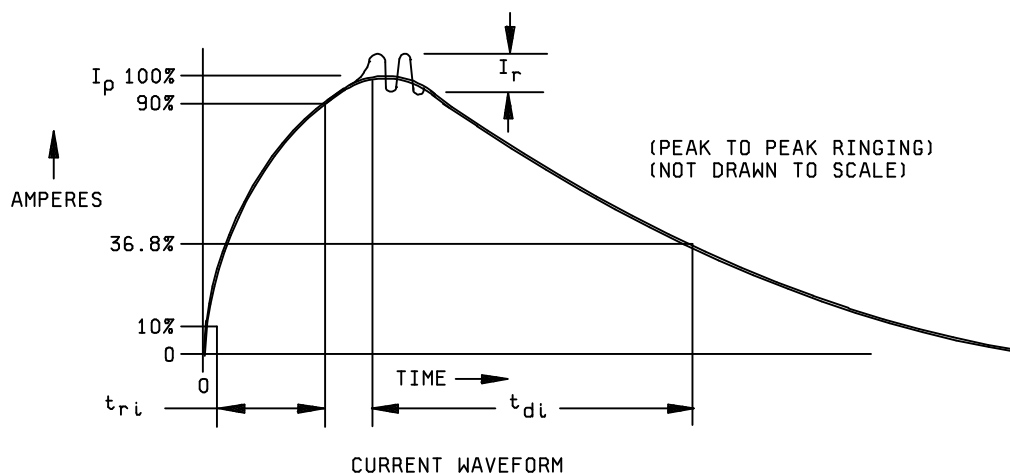
(Bounceless, mercury wetted, or equivalent)

(Open during discharge pulse and capacitance measurement)

NOTES:

1. The performance of this simulator circuit is strongly influenced by parasitics. Capacitances across relays and resistor terminals, and series inductance in wiring and in all components shall be minimized.
2. As a precaution against transients upon recharge of $C1$, the supply voltage V_S may be reduced before switch $S1$ is returned to the charging position.
3. Piggybacking DUT sockets is not permitted during verification or classification testing.
4. Switching terminals A and B internal to the simulator to obtain opposite polarity is not recommended.
5. $C1$ represents the effective capacitance (see 2.3.2).
6. The current probe connection shall be made with double shielded cable into a 50-ohm termination at the oscilloscope. The cable length shall not exceed 3 feet.

FIGURE 3015-1. EDS classification test circuit (human body model).



NOTES:

1. The current waveforms shown shall be measured as described in the waveform verification procedure of 3.2, using equipment meeting the requirements of 2.
2. The current pulse shall have the following characteristics:

T_{ri} (rise time) -----Less than 10 nanoseconds.

T_{di} (delay time) ----- 150 ± 20 nanoseconds.

I_p (peak current) -----Within ± 10 percent of the I_p value shown in table II for the voltage step selected.

I_r (ringing) -----The decay shall be smooth, with ringing, break points, double time constants or discontinuities less than 15 percent I_p maximum, but not observable 100 nanoseconds after start of the pulse.

FIGURE 3015-2. EDS classification test circuit waveforms (human body model).

ACTIVATION TIME VERIFICATION

1. **PURPOSE.** This method establishes a means for assuring circuit performance during cold temperature start up. It defines an activation time for digital microelectronic devices such as TTL, DTL, RTL, ECL, and MOS and establishes the procedure necessary to accomplish the required testing. This method will ensure that a specified capability is available a known time interval after application of power.

1.1 **Definitions.** The following definitions shall apply for the purposes of this test method:

- a. **Activation time.** Activation time is defined as the time required for a device to become functionally operable after initial power is applied at the operating temperature extremes as specified by the applicable acquisition document. Note that activation time may be due to device and test system limitations, or both.
- b. **Maximum and minimum.** Maximum and minimum refer to an algebraic system where "max" represents the most positive value of the range and "min" represents the least positive value of the range. This is consistent with MIL-STD-1331, 30.1 and 30.2 for logic levels only.
- c. **Maximum operating frequency.** Maximum operating frequency is defined as the frequency of operation resulting from use of the minimum clock period for devices requiring a clock, or the frequency of operation resulting from the use of the minimum cycle time for devices not requiring a clock (such as memory devices) as specified in the applicable acquisition document.

1.2 **Symbols.** The following symbols and definitions shall apply for the purposes of this method.

1.2.1 **Logic levels.**

- a. V_{LW} = worst case nominal low level logic input. The maximum allowable V_{IL} specified in the applicable acquisition document minus 100 millivolts to allow for uncertainty in the drive level capability of high speed functional test equipment. ($V_{LW} = V_{IL}(\text{max}) - 100 \text{ mV}$).
- b. V_{HW} = worst case nominal high level logic input. The minimum allowable V_{IH} as specified by the applicable acquisition document plus 100 millivolts ($V_{HW} = V_{IH}(\text{min}) + 100 \text{ mV}$).
- c. $V_{OH}(\text{min})$ = minimum output high level specified for a digital microelectronic device.
- d. $V_{OL}(\text{max})$ = maximum output low level specified for a digital microelectronic device.

1.2.2 **Activation times.**

- a. t_{AH} = maximum allowable activation time requirement, measured at $V_{CC}(\text{max})$.
- b. t_{AL} = maximum allowable activation time requirement, measured at $V_{CC}(\text{min})$.

2. **APPARATUS.** An instrument shall be provided which has the capability of applying sequential logic patterns to the device under test in accordance with the applicable acquisition document. The test instrument shall also be capable of applying nominal power supply voltage(s) and monitoring the output for the specified logic levels. The output monitoring circuit shall be of the double comparator type. The threshold voltage (trip point) for a comparator shall be $V_{OL}(\text{max})$ and $V_{OH}(\text{min})$ as specified in the applicable acquisition document. The test chamber shall be capable of maintaining the device under test at any specified test temperature.

3. **PROCEDURE.** The device shall be thermally stabilized at the minimum specified test temperature with no power applied to the device. The specified power supply voltage and the specified input logic patterns using V_{LW} and V_{HW} input voltage levels shall then be applied to the device under test and the outputs shall be monitored as described in section 2. This functional test shall be performed at a speed of at least 75 percent of $F(\text{max})$ using a test vector pattern as called out in the applicable acquisition document that has been designed for maximum fault coverage with no more than 4 K vectors.

3.1 Activation time, maximum supply voltage, t_{AH} . Available test equipment has inherent delays (due to test program statement execution, voltage driver rise/fall times, etc.) between the time power is applied to the device under test and actual execution of the test. Therefore, the activation time stated in the applicable acquisition document should not be specified as less than the test system delay (even though device performance may be better). The test sequence shall be as follows.

3.1.1 Device under test. The device under test shall be thermally stabilized at the minimum specified test temperature, with the device unpowered.

3.1.2 Device under test shall then be powered up at V_{CC} (max). After waiting the time specified by T_{AH} (taking into account test equipment delays), the functional test pattern (using V_{LW} and V_{HW} logic levels) shall be applied to verify proper operation.

3.1.3 Repeat sequences 3.1.1 and 3.1.2 at the maximum specified test temperature.

3.2 Activation time, minimum supply voltage, t_{AL} . Repeat sequence described in 3.1.1 to 3.1.3 using a supply voltage of V_{CC} (min).

3.3 Failure criteria. The device must pass the functional test pattern and is a failure if the device fails any single pattern or vector in the specified test set.

4. SUMMARY. The following details, when applicable, shall be as specified in the applicable acquisition document:

- a. V_{IL} (max).
- b. V_{IH} (min).
- c. V_{OH} (min).
- d. V_{OL} (max).
- e. V_{CC} (min).
- f. V_{CC} (max).
- g. Test temperature (min and max operating temperature).
- h. t_{AH} (max).
- i. t_{AL} (max).
- j. Functional test pattern (see 3).
- k. Maximum operating frequency, F (max) (see 1.1.c).

MICROELECTRONICS PACKAGE DIGITAL SIGNAL TRANSMISSION

1. PURPOSE. This method establishes the means of evaluating the characteristic impedance, capacitance, and delay time of signal lines in packages used for high frequency digital integrated circuits. It is intended to assure a match between circuit performance and interconnecting wiring to minimize signal degradation.

1.1 Definitions.

1.1.1 Characteristic impedance. The impedance that a section of transmission line exhibits due to its ratio of resistance and inductance to capacitance.

1.1.2 Delay time. The time delay experienced when a pulse generated by a driver with a particular drive impedance is propagated through a section of transmission line.

1.2 Symbols.

R: Resistance
L: Inductance
C: Capacitance
 t_{pd} : Propagation delay time

2. APPARATUS. The approaches for transmission performance measurements shall include a suitable time domain reflectometer (TDR) (see 2.1) and dc resistance measuring equipment (see 2.2).

2.1 Time domain reflectometer. The TDR used for this test shall have a system rise time for the displayed reflection that is not less than 5 times and preferably 10 times the rise time (method 3004) for the candidate integrated circuits to be packaged. Interconnecting cables and fixtures shall be designed such that this ratio is not degraded due to reflections and ringing in the test setup.

2.2 DC resistance. DC resistance measuring equipment and probe fixtures shall be capable of measuring the resistance of the package leads and the chip-to- package interconnect media with an accuracy of no greater than ± 10 percent of the actual value including errors due to the mechanical probing interface contact resistance.

3. PROCEDURE. The test equipment configuration shall be as shown on figure 3017-1 using a time domain reflectometer as specified (see 2). The characteristic impedance (Z_0), propagation time (t_{pd}), resistance and load capacitance (C_L) shall be measured for all representative configurations as determined by a review of the package drawings, and the intended applications (see 3.2 through 3.3).

3.1 General considerations.

3.1.1 TDR measurements. Accurate measurement of transmission performance of a package pin using a TDR requires careful design and implementation of adapter fixtures to avoid reflections due to transmission line discontinuities in the cables and junctions between the TDR and the package being tested. The accuracy of the measurement will be enhanced if the coaxial cable used to interface to the package is of a characteristic impedance as close as possible to the package pin impedance. The interface to the package should be a soldered connection and mechanical design of the actual coax-to-package interface should minimize the length of the uncontrolled impedance section. Stripline interfaces are the best method for surface mount package styles.

3.1.2 Test configurations. Obtaining a good high frequency ground is also important. Connection of the package ground plane (if the package design has one) to the test set-up ground plane should be accomplished with a pin configuration similar to actual usage in the intended package applications.

Pin selection for testing may vary according to package complexity. For packages with very symmetrical pin configurations only a few pins need be tested but configurations must include pins adjacent and nonadjacent to the ground pins. Packages with complex wiring and interconnection media should be tested 100 percent.

3.2 Test procedure for package transmission characteristics. Using a section of coaxial cable of known, calibrated characteristic impedance (Z_{Ref}) as a reference measure the minimum (Z_{Min}) maximum (Z_{Max}) and average (Z_o) values of reflection coefficient (ρ) for the section of line on the TDR display that has been carefully determined to be the package pin (locate using zero-length short circuits).

Calculate characteristic impedance (Z_o) for each of the cases from the formula:

$$Z_o = Z_{Ref} \times \frac{(1 + \rho)}{(1 - \rho)}$$

3.2.2 Delay time measurement. From the TDR display of 3.2.1 measure the time difference in picoseconds from the point identified as the start of the exterior package pin (t_1) to the chip interface point (t_2) ($\Delta t = t_1 - t_2$)

Form the package design drawings, determine the physical length of the package run (L)

$$\text{Time delay } t_{pd} = \frac{\Delta t}{L}$$

3.2.3 Load capacitance calculation.

$$\text{Load capacitance } C_L = \frac{t_{pd}}{Z_o}$$

3.2.4 Load inductance calculation.

$$\text{Load inductance (series)} = \frac{(t_{pd})^2}{C_L}$$

3.3. Series resistance measurement.

Using the test setups of figure 3017-2, separately measure the dc resistance of the chip-to-package interface media (R_M) and the package lead (R_L).

4. SUMMARY. The following details, when applicable, shall be specified in the applicable acquisition document:

- a. Z_{Max} .
- b. Z_{Min} .
- c. Z_o (max).
- d. Z_o (min).
- e. t_{pd} (max).
- f. t_{pd} (min).
- g. C_L (max).

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- h. C_L (min).
- i. L_L (max).
- j. L_L (min).
- k. R_M (max).
- l. R_M (min).
- m. R_L (max).
- n. R_L (min).
- o. Package pins to be tested.
- p. Package ground configuration.

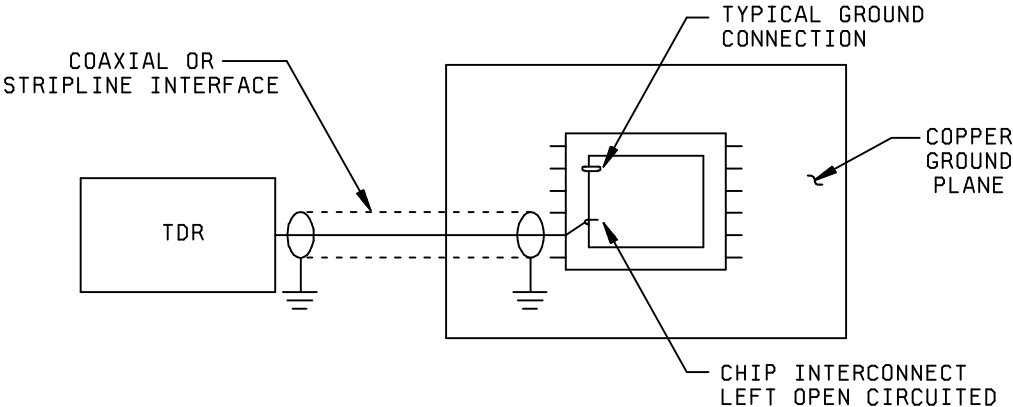


FIGURE 3017-1. Time domain reflectometer test setup.

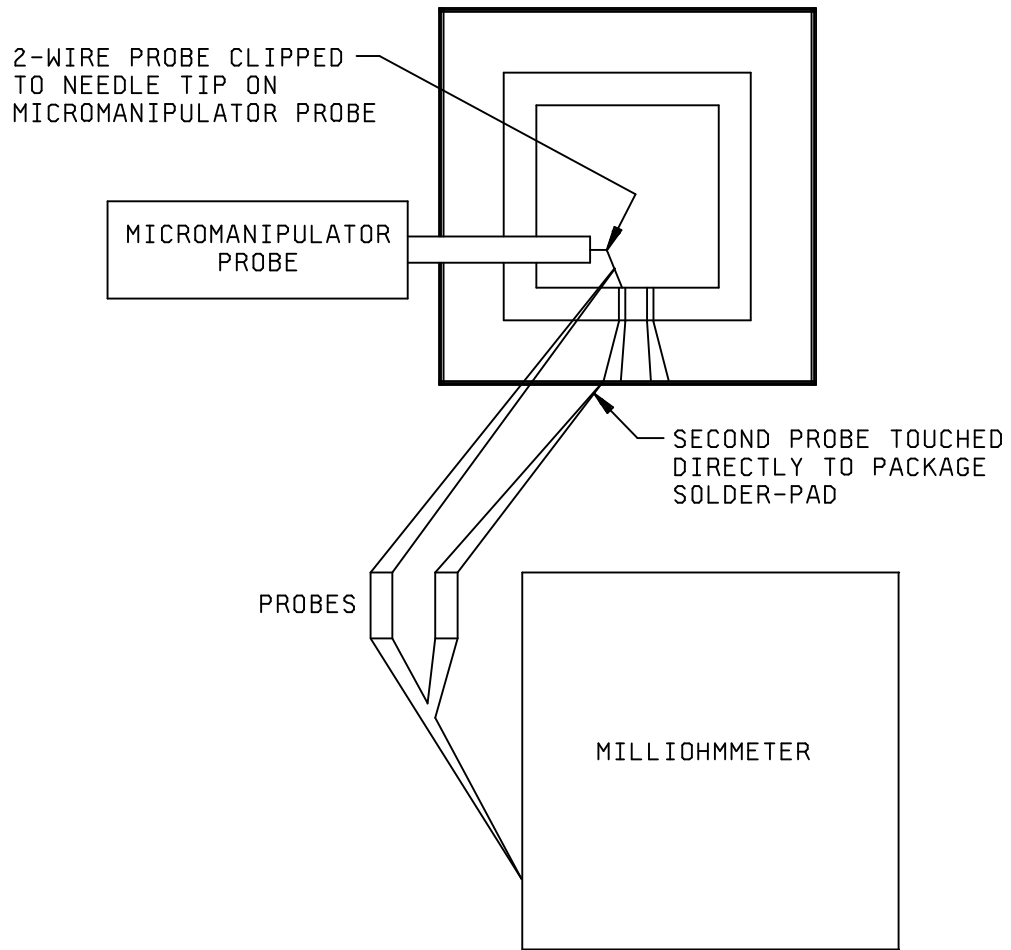


FIGURE 3017-2. Test setup for dc resistance using a milliohmmeter.

CROSSTALK MEASUREMENTS FOR DIGITAL MICROELECTRONICS DEVICE PACKAGE

1. PURPOSE. This method establishes the means of measuring the level of cross-coupling of wideband digital signals and noise between pins in a digital microcircuit package. The method may be used to gather data that are useful in the prediction of the package's contribution to the noise margin of a digital device. The technique is compatible with multiple logic families provided that the drive and load impedance are known.

1.1 Definitions.

1.1.1 Crosstalk. Signal and noise waveforms coupled between isolated transmission lines, in this case, package conductors.

1.1.2 Coupling capacitance. The effective capacitance coupling between a pair of conductors in a package as measured by the time constant of the charge pulse applied on one line and measured on the other.

1.1.3 Noise pulse voltage. The voltage of a crosstalk measured at the minimum noise pulse width as measured on a receiver input line.

1.1.4 Peak noise voltage. The peak value of the noise pulse measured on a receiver input line.

1.2 Symbols. The following symbols shall apply for the purpose of this test method and shall be used in accordance with the definitions provided (see 1.2.1 and 1.2.2).

1.2.1 Logic levels.

$V_{OL(max)}$: The maximum output low level specified in a logic system.

$V_{OH(min)}$: The minimum output high level specified in a logic system.

$V_{IL(max)}$: The maximum allowed input low voltage level in a logic system.

$V_{IH(min)}$: The minimum allowed input high level in a logic system.

1.2.2 Noise pulse width.

t_{PL} : The low level noise pulse width, measured at the $V_{IL(max)}$ level (see method 3013).

t_{PH} : The high level noise pulse width, measured at the $V_{IH(min)}$ level (see method 3012).

1.2.3 Transition times (see method 3004).

t_{ILH} : Rise time. The transition time of the output from the 10 percent to the 90 percent of the high voltage levels with the output changing from low to high.

t_{IHL} : Fall time. The transition times from the 90 percent to the 10 percent of the high voltage level with the output changing from high to low.

1.2.4 Crosstalk parameters.

C_c : Coupling capacitance (see 1.1.2).

V_N : Noise pulse voltage (see 1.1.3).

V_{NPK} : Peak noise voltage (see 1.1.4).

2. APPARATUS. The apparatus used for crosstalk measurements shall include a suitable source generator (see 2.1), wideband oscilloscope (see 2.2), low capacitance probe (see 2.3) and load resistors (see 2.4).

2.1 Source generator. The source generator for this test shall be capable of duplicating (within 5 percent) the transition times, V_{OH} and V_{OL} levels of the logic system(s) being considered for application using the package style under evaluation. The source generator shall have a nominal characteristic source impedance of 50 ohms.

2.2 Wideband oscilloscope. The oscilloscope used to measure the crosstalk pulse shall have a display risetime that is less than 20 percent of the risetime of the logic systems being considered for application in the package style under evaluation. A sampling-type oscilloscope is recommended.

2.3 Low capacitance probe. The interface between the oscilloscope and the unit under test shall be a high impedance low capacitance probe. The probe impedance shall be 10 k Ω , minimum and the capacitance shall be 5 pF, maximum, unless otherwise specified in the acquisition document.

2.4 Load resistor. The load resistors specified for this test shall be low inductance, low capacitance, chip style resistors with a tolerance of ± 5 percent. Load resistor value(s) shall be specified by the acquisition document to match the load impedance levels of the application logic family for a single receiver load.

3. PROCEDURE. The test equipment configuration shall be as shown on figure 3018-1 using a source generator, oscilloscope, probe and loads as specified (see 2). Measurements shall be made of coupling capacitance, (see 3.2) and if required by the acquisition document, of noise pulse voltage, peak noise pulse voltage, and noise pulse width (see 3.3).

3.1 General considerations.

3.1.1 Package test configuration. It is important to ground the package using the same pins as would be used in the microcircuit application. If the package has an internal ground plane or ground section, this should be connected via package pin(s) to the exterior test set-up ground plane. The package should be connected to the test set-up with coaxial cable or stripline. Unshielded conductor medium should not be used between the signal source and package. Coaxial shields must be grounded at both ends of the cable. Package sockets should not be used unless these are to be part of the microcircuit application configuration. Package leads must be formed and trimmed as specified in the application. Package-to-chip interconnecting media shall be installed in the package and used to connect to the load resistors.

3.1.2 Pin selection. For simple packages with symmetrical, parallel pin conductors, only a sample of pin combinations need be tested. Unless otherwise specified by the acquisition document, all combinations adjacent to the ground pin(s) and combinations opposite the ground pin(s) shall be tested, as a minimum. Complex packages with nonparallel conductors or multilayer wiring shall be tested for all adjacent-pair combinations, unless otherwise specified.

3.2 Coupling capacitance measurements. Connect the test equipment as shown on figure 3018-1. Use a 50 ohm chip resistor load in the driven pin channel, unless otherwise specified. For the pick-up channel, use the load resistor value(s) as specified by the acquisition document. (Load resistor values should be set such that the parallel combination of load resistance and probe impedance matches as closely as practical the specified load impedance of a single receiver in the logic system to be used in the microcircuit application.) Check the residual cross-coupling of the measuring set-up by touching the probe to the pick-up channel load before the pick-up pin is connected to the resistor. Measure and record the peak pulse voltage observed. This peak pulse reading must be less than 50 percent of the reading observed with the pin connected to the resistor for a reading to be valid. Adjust the test set-up cable orientation and configuration to minimize this residual cross-coupling.

Connect the pick-up pins to the load resistor and adjust the pulse width so that the time required to charge the coupling capacitance to 0 V can be observed. Measure the time at the 63 percent voltage point on the waveform (T) and calculate coupling capacitance (C_C) as follows:

$$\text{Determine } R_{Total} = \frac{R_{Probe} \times R_{Load}}{R_{Probe} + R_{Load}}$$

$$C_{Total} = \frac{T}{R_{Total}}$$

$$C_C = C_{Total} - C_{Probe}$$

Values of C_C can be used as a relative measure for comparison of potential crosstalk among several packages to a standard package. The coupling capacitance (C_C) can also be used to predict levels of crosstalk for various logic systems or circuit configurations by performing a pulse response analysis using a circuit simulator.

3.3 Noise pulse measurements. Using the same test setup as in 3.2, measure the crosstalk noise pulse voltage at the minimum noise pulse width specified for the logic system or as specified by the acquiring agency.

Measure the peak noise voltage value of the coupled crosstalk.

4. SUMMARY. The following details, when applicable, shall be specified in the acquisition document:

- a. C_C .
- b. V_{OL} (max).
- c. V_{OH} (min).
- d. V_{IL} (max).
- e. V_{IH} (min).
- f. t_{PL} .
- g. t_{PH} .
- h. t_{ILH} .
- i. t_{IHL} .
- j. V_N .
- k. V_{NPK} .

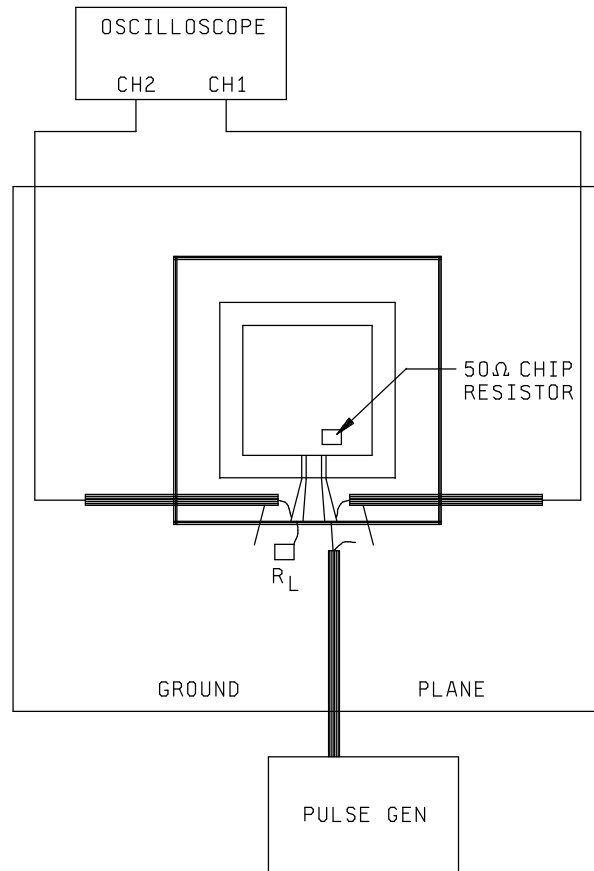


FIGURE 3018-1. Test setup for coupling capacitance measurement.

METHOD 3019.1

GROUND AND POWER SUPPLY IMPEDANCE MEASUREMENTS FOR MICROELECTRONICS DEVICE PACKAGE

1. PURPOSE. This method establishes the means of measuring the series impedance of the ground and power supply circuit pin configurations for packages used for complex, wide bandwidth microcircuits. The method provides data that are useful in the evaluation of the relative performance of various packages and can be used to predict the contribution of the package to power supply noise and ground noise.

1.1 Definition.

1.1.1 Ground or power supply impedance. The series combination of inductive reactance and resistance exhibited by all of the conductor paths between the semiconductor chip interface and the exterior package interface in either the ground circuit or the power supply circuit. The impedance of a series inductive circuit is defined by the equation:

$$Z = \sqrt{R^2 + X^2 L}$$

1.2 Symbols. The following symbols shall apply for purposes of this test method and shall be used in conjunction with the definition provided in 1.1.

L_G : Series inductance of the ground circuit path in a package (henries).

L_p : Series inductance of the power supply circuit path in a package (henries).

X_G : Series inductive reactance of ground path = $2 \pi f L_p$ (ohms).

X_p : Series inductive reactance of power supply path = $2 \pi f L_p$ (ohms).

f : Frequency (Hz).

f_{tr} : Frequency of primary component of digital pulse transition = $\frac{1}{t_t}$ (Hz).

f_{tp} : Frequency related to noise pulse width specified for the logic system:

$$f_{tp} = \frac{1}{t_{Pmin}} \text{ (Hz)}$$

t_t : Transition time from logic system. Equal to the smaller value of low to high or high to low transition.

Z_G : Series impedance of ground path at frequency:

$$Z_G = \sqrt{R_G^2 + X_G^2}$$

Z_p : Series impedance of power supply path at frequency:

$$Z_p = \sqrt{R_p^2 + X_p^2}$$

t_{Pmin} : The minimum noise pulse width at either the V_{IH} or V_{IL} level specified for a given logic system.

2. APPARATUS. The apparatus used for ground impedance measurements shall include a suitable RF inductance meter and a suitable milliohmmeter.

2.1 RF inductance meter. The RF inductance meter (or multi-frequency LCR meter) shall be capable of ac measurements of series inductance over the range of 1 nH to 1,000 nH at a frequency of 100 kHz with an accuracy of ± 5 percent including test fixture errors.

2.2 Milliohmmeter. The milliohmmeter (or LCR meter) shall be capable of measuring resistance using a 4-wire method over the range from 10 M Ω to 10 Ω with an accuracy of ± 5 percent, including test fixture errors.

3. PROCEDURE. Measurement of series ground impedance (Z_G) and power supply impedance (Z_p) shall be made for all standard power and ground configurations specified for the package application. Measurements shall be performed in accordance with 3.2.

3.1 General considerations. Accurate measurement of series impedance requires careful design and implementation of test adapters to minimize errors. Since the inductance and resistance values being measured are usually quite small, means must be provided to null out the tare resistance and inductance of the test adapters through 4-wire methods and subtraction techniques. The tare values of the interconnecting circuits must be small to enable the meters to read on ranges that provide adequate resolution and accuracy. The techniques specified herein are adequate for predicting impedance at frequencies up to 1 GHz. Impedance shall be evaluated at a frequency related to either the transition time:

$$f_{tr} = \frac{1}{t_{tr}}$$

or to the noise pulse width of the logic system used in the package:

$$f_{tp} = \frac{1}{t_{Pmin}}$$

The frequency f shall be as specified in the acquisition document.

The configuration of the package being tested must be the same as in the application. Wirebonds and other interconnection media must be included in the measurement. The package should be mounted on a dielectric holding fixture to avoid stray capacitance between the package and test equipment ground planes. Sockets should not be used unless specified. Package leads must be trimmed to applications specifications.

3.2 Test procedure for series impedance.

3.2.1 Series inductance. With the inductance meter, measure the series inductance of the power supply circuit (L_p) between the external package solder interface and the chip power supply location. Similarly, measure the inductance of the ground circuit (L_G). Calculate $X_p = 2 \pi f L_p$ and $X_G = 2 \pi f L_G$.

3.2.2 Series resistance. With the milliohmmeter, measure the series resistance of the same power and ground circuits: R_p and R_G .

3.2.3 Calculation of impedance.

$$\text{Calculate } Z_p = \sqrt{X_p^2 + R_p^2}$$

$$A_G = \sqrt{X_G^2 + R_G^2}$$

4. SUMMARY. The following details, when applicable, shall be specified in the applicable acquisition document.

- a. Z_p (max).
- b. Z_G (max).
- c. L_p (max).
- d. L_G (max).
- e. R_p (max).
- f. R_G (max).
- g. f.
- h. f_{tr} .
- i. f_{tp} .
- j. t_t .
- k. t_{Pmin} .

HIGH IMPEDANCE (OFF-STATE) LOW-LEVEL OUTPUT LEAKAGE CURRENT

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to output leakage current when an output is in the high-impedance state with a low-level voltage applied. This current should normally be specified as a maximum negative value (I_{OLZ} maximum). This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL, and MOS that have tristate outputs.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified test temperature. An instrument shall be provided that has the capability of applying the specified low level voltage to the output terminal and measure the resultant current flowing in the terminals.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Apply voltages to the test circuit as follows:

- a. Worst-case power supply voltage (V_{CC}) applied to the V_{CC} terminal.
- b. Threshold-level voltages (V_{IH} minimum or V_{IL} maximum) applied to the control inputs which forces the output under test into the high-impedance (off) state.
- c. Nonthreshold level voltage applied to the logic input terminals controlling the output under test so as to produce a "hard" high voltage level at that output if the output was not in the high-impedance state. Apply the specified low logic level voltage to the output terminal under test and measure the resultant leakage current. Outputs shall be measured individually.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Worst case power supply voltages.
- c. Threshold voltage levels for control inputs.
- d. Voltages at logic input terminals for output under test.
- e. Output voltage.
- f. I_{OLZ} maximum negative limit.

HIGH IMPEDANCE (OFF-STATE) HIGH-LEVEL OUTPUT LEAKAGE CURRENT

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to output leakage current when an output is in the high-impedance state with a high-level voltage applied. This current should normally be specified as a maximum positive value (I_{OHZ} maximum). This method applies to digital microelectronic devices, such as TTL, DTL, RTL, ECL and MOS that have tristate outputs.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified test temperature. An instrument shall be provided that has the capability of applying the specified high level voltage to the output terminal and measure the resultant current flowing out of the terminals.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Apply voltages to the test circuit as follows:

- a. Worst-case power supply voltage (V_{CC}) applied to the V_{CC} terminal.
- b. Threshold level voltage (V_{IH} minimum or V_{IL} maximum) applied to the control inputs which will cause the output under test to be in the high-impedance (off) state.
- c. Nonthreshold level voltage applied to the logic input terminals controlling the output under test so as to produce a "hard" low voltage level at that output if the output was not in the high-impedance state. Apply the specified high logic level voltage to the output terminal under test and measure the resultant leakage current. Outputs shall be measured individually.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Worst case power supply voltages.
- c. Threshold voltage levels for control inputs.
- d. Voltages at logic input terminals for output under test.
- e. Output voltage.
- f. I_{OLZ} maximum positive limit.

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METHOD 3022

INPUT CLAMP VOLTAGE

1. PURPOSE. This method establishes the means for assuring circuit performance to the limits specified in the applicable acquisition document in regard to input voltage levels in a region of relatively low differential resistance that serve to limit the input voltage swing. Input clamp voltage is specified as a maximum positive value (V_{IC} POS) or the maximum negative value (V_{IC} NEG). This method applies to digital microelectronic devices.

2. APPARATUS. The test chamber shall be capable of maintaining the device under test at any specified test temperature. The test apparatus shall be capable of supplying the worst case power supply voltage and shall be capable of loading the input of the circuit under test with the specified negative current or the specified positive current, both referred to as I_{IN} . Resistors may be used to simulate the applicable current levels.

3. PROCEDURE. The device shall be stabilized at the specified test temperature. Apply worst-case power supply voltage (V_{CC}) to the V_{CC} terminal. Force the specified negative current from or the positive current into the input under test and measure the resultant input voltage. (NOTE: Any input for which the I_{IL} would influence the negative input current (I_{IN}) should have V_{IC} measured with the V_{CC} terminal open). All input terminals not under test may be high, low, or open to minimize or inhibit any outside factors (noise, transients, etc.) from affecting the test. Inputs shall be tested individually.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test temperature.
- b. Worst case power supply voltage.
- c. Current to be forced from the input terminal.
- d. V_{IC} (POS) or V_{IC} (NEG) maximum limit.

MIL-STD-883E

METHOD 3023

STATIC LATCH-UP MEASUREMENTS
FOR DIGITAL CMOS MICROELECTRONIC DEVICES

Latchup shall be performed in accordance with JEDEC-STD-17 dated August 1988.

SIMULTANEOUS SWITCHING NOISE MEASUREMENTS
FOR DIGITAL MICROELECTRONIC DEVICES

1. Purpose. This method establishes the procedure for measuring the ground bounce (and V_{CC} bounce) noise in digital microelectronic devices or to determine compliance with specified ground bounce noise requirements in the applicable acquisition document. It is also intended to provide assurance of interchangeability of devices and to eliminate misunderstanding between manufacturers and users on ground bounce noise test procedures and requirements. This procedure is not intended to predict the amount of noise generated on an end product board, but for use in measuring ground bounce noise using a standardized method for comparing noise levels between logic families and vendors.

1.1 Definitions. The following definitions shall apply for the purposes of this test method:

- a. Ground bounce noise. The voltage amplitude (peak) of extraneous signals present on a low-level non-switching output with a specified number of other outputs switching. Ground bounce noise on a logic low output can be of sufficient amplitude to exceed the high level threshold of a receiver, or cause latch-up on unprotected CMOS inputs.
- b. V_{CC} bounce noise. The voltage amplitude (peak) of extraneous signals present on a high-level non-switching output with a specified number of other outputs switching. V_{CC} bounce on a logic high output can be of sufficient amplitude to exceed the low level threshold of a receiver, or cause latch-up on unprotected CMOS inputs.
- c. Simultaneous switching noise. Noise generated across the inductance of a package pin as a result of the charge and discharge of load capacitance through two or more transitioning output pins.
- d. Quiet low. A non-switching output which is driving a nominal low level.
- e. Quiet high. A non-switching output which is driving a nominal high level.
- f. Signal skew. The amount of time measured between any two signal transitions at the 1.5 V voltage level (for TTL threshold devices) and at $V_{CC}/2$ (for CMOS threshold devices).

1.2 Symbols. The following symbols shall apply for the purposes of this test method:

1.2.1 Logic levels.

- V_{IL} max: The maximum allowed input low level on a digital microelectronic device.
- V_{IL} min: The minimum allowed input low level on a digital microelectronic device.
- V_{IH} max: The maximum allowed input high level on a digital microelectronic device.
- V_{IH} min: The minimum allowed input high level on a digital microelectronic device.

1.2.2 Noise levels.

V_{OLP} max: The largest positive amplitude transient allowed on a logic low output.

V_{OLV} max: The largest negative amplitude transient allowed on a logic low output.

V_{OHP} max: The largest positive amplitude transient allowed on a logic high output.

V_{OHV} max: The largest negative amplitude transient allowed on a logic high output.

1.2.3 Transition times.

T_{TLH} : The transition time of a rising edge (rise time) measured from 10 percent to 90 percent.

T_{THL} : The transition time of a falling edge (fall time) measured from 90 percent to 10 percent.

2. Apparatus. The apparatus used for ground bounce noise measurements shall include a suitable source generator (see 2.1), loads (see 2.2), an oscilloscope (see 2.3) and a low noise test fixture (see 2.4). See figure 3024-1 for proper connections.

2.1 Source generator. The pulse or pattern generator for this test shall be capable of supplying the required input pulses with transition times of 3.0 ± 0.5 ns to minimize skew due to input threshold differences.

2.2 Loads. Loads shall consist of 50 pF capacitance (-0,+20%) and a 500 ohm ($\pm 1\%$) low inductance resistor from each output to ground. Capacitance value should include probe and test fixture capacitance. The 500 ohm resistor may be made up of a 450 ohm resistor in series with a 50 ohm oscilloscope input channel or 50 ohm termination.

2.3 Oscilloscope. The oscilloscope and probe combination shall have a minimum bandwidth of 1 GHz. Probes (if used) must be calibrated using the manufacturers instructions before accurate measurements can be made.

2.4 Test fixture. Test fixture construction has a large impact on the accuracy of the results. Therefore, the standard ESH test fixture or an equivalent approved fixture (one which demonstrates results within 10% of the standard) must be used to perform these tests. (The ESH fixture for DIP devices is LAB-350-28. Other standard fixtures will be determined at a later date.) Lead lengths should be 0.25 inches or less. The devices under test may be clamped to the test fixture, soldered to the fixture, or installed in a socket on the fixture. Use of a socket may result in higher readings.

3. Procedure. The device shall be installed on the low noise fixture. All outputs of the device under test shall be loaded as specified in 2.2. All outputs (as many as functionally possible) shall be conditioned to switch using the setup information in 3.1. Tests shall be performed using the procedures in 3.2.

3.1 Setup parameters.

3.1.1 Supply voltage. Power supply voltage shall be at nominal operating voltage (5.0 volts for most families).

3.1.2 Test temperature. All tests shall be performed at 25°C.

3.1.3 Input conditioning. Input voltage levels shall be 0.0 V low level and V_{CC} for CMOS and 3.0 V for TTL for high level for both static and switching inputs. Switching inputs shall be driven by 1 MHz signals with 2.0 ± 0.5 ns transition times. Maximum skew (made at the device package inputs) between any two input signals (including out-of-phase signals) shall be less than 1 ns. See figure 3024-2.

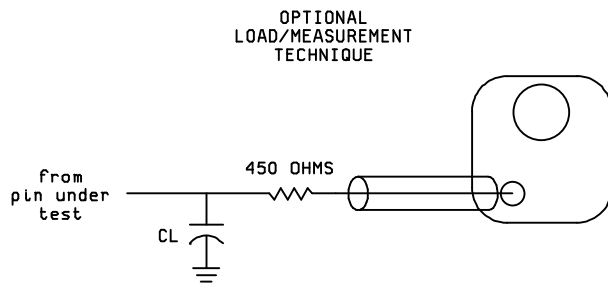
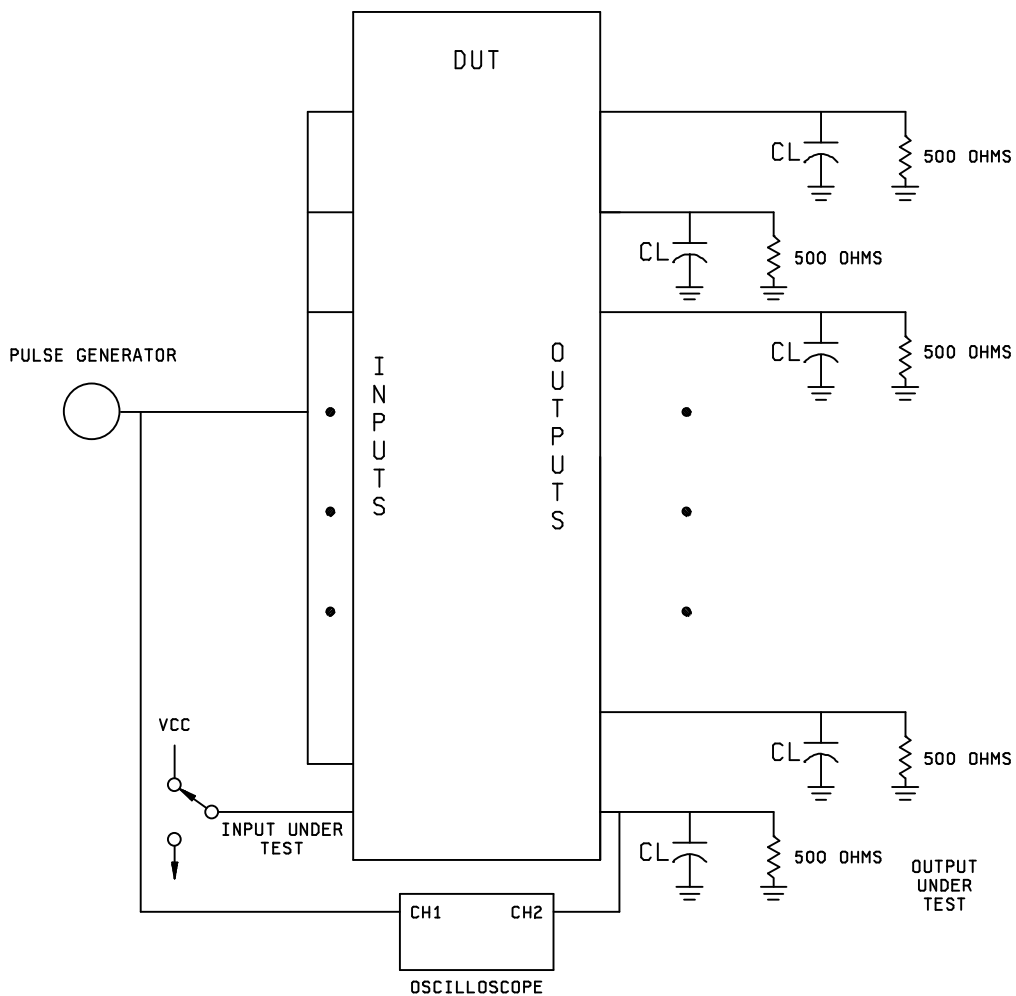


FIGURE 3024-1. Simultaneous switching noise test setup.

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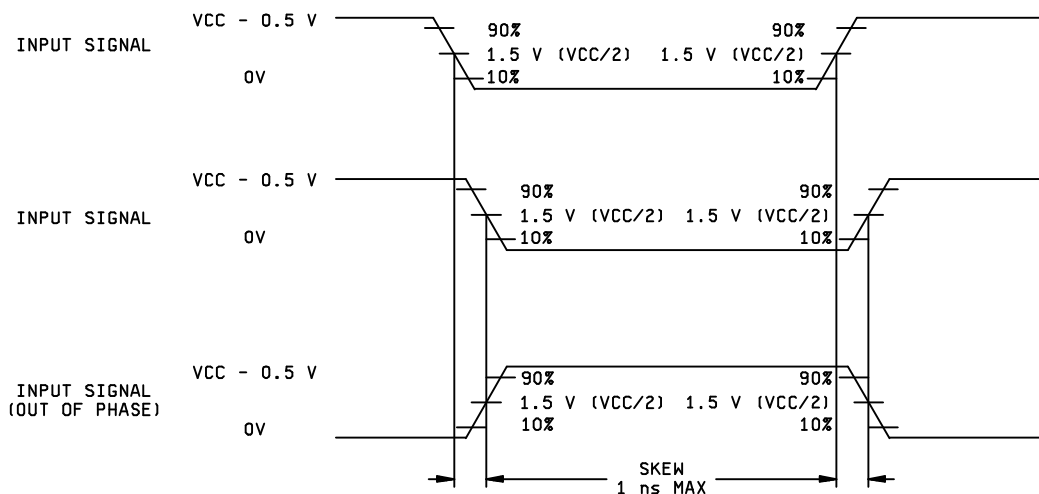


FIGURE 3024-2. Input waveforms.

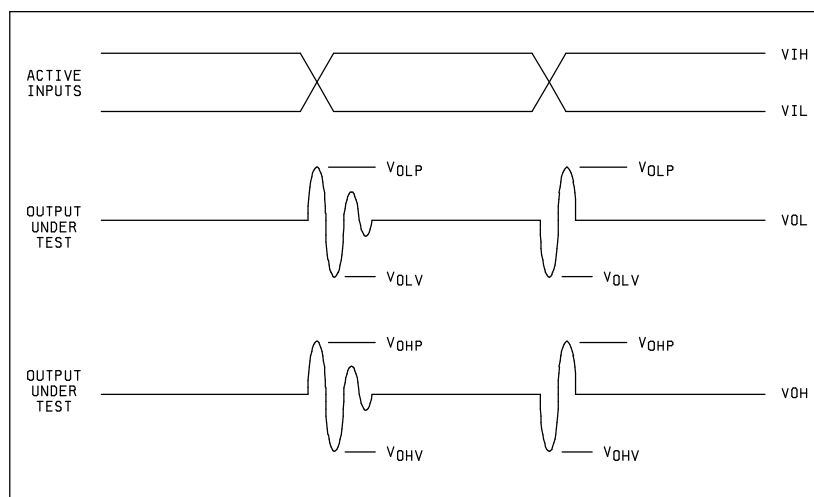


FIGURE 3024-3. Noise measurement technique.

3.2. Ground bounce test procedure. The output to be tested should be conditioned to a low level. The scope probe (if used) shall be connected to the output under test no more than 0.25 inches from the pin. The probe ground lead shall be attached to a suitable location (ground plane or pin) and have a maximum length of 1 inch. The ground bounce noise is the peak voltage in the positive (V_{OLP}) and negative (V_{OLV}) directions measured from the nominal V_{OL} level (see figure 3024-3). The noise must be measured at both the LOW to HIGH and the HIGH to LOW transition of the switching outputs. (Two consecutive areas of disruption need to be analyzed for the largest peak. If a second scope channel is available, it can be used to monitor the switching outputs and ease synchronization of the noise.) This test shall be repeated with each output at a low level with all others (functionally possible) switching. The largest peak on the worst output is the device ground bounce noise. Engineering judgement or experience may be used to reduce the number of pins tested provided that the rationale for this reduction of pins tested is documented and made available to the preparing activity or the acquiring activity upon request. (Generally, the noisiest pin on one device will be the noisiest pin on all devices of that type.)

3.3 V_{CC} bounce test procedure. The output to be tested should be conditioned to a high level. The scope probe (if used) shall be connected to the output under test no more than 0.25 inches from the pin. The probe ground lead shall be attached to a suitable location (ground plane or pin) and have a maximum length of 1 inch. The V_{CC} bounce noise is the peak voltage in the positive (V_{OHP}) and negative (V_{OHV}) directions measured from the nominal V_{OH} level. The noise must be measured at both the LOW to HIGH and the HIGH to LOW transition of the switching outputs. (Two consecutive areas of disruption need to be analyzed for the largest peak. If a second scope channel is available, it can be used to monitor the switching outputs and ease synchronization of the noise.) This test shall be repeated with each output at a high level with all others (functionally possible) switching. The largest peak on the worst output is the device V_{CC} bounce noise. Engineering judgement or experience may be used to reduce the number of pins tested provided that the rationale for this reduction of pins tested is documented and made available to the preparing activity or the acquiring activity upon request. (Generally, the noisiest pin on one device will be the noisiest pin on all devices of that type.)

4. Summary. The following details, when applicable, shall be specified in the acquisition document:

- a. V_{CC} Supply voltage.
- b. Test temperature.
- c. Input switching frequency.
- d. Number of outputs switching.
- e. Package style of devices.
- f. Conditioning levels of non-switching inputs.
- g. Output pin(s) to be tested.

METHOD 4001.1

INPUT OFFSET VOLTAGE AND CURRENT AND BIAS CURRENT

1. PURPOSE. This method establishes the means for measuring input bias current and the offset in voltage and current at the input of a linear amplifier with differential inputs. Offset voltage may also be pertinent in some single input amplifiers. Input bias current will also be measured in this procedure.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Input offset voltage (V_{IO}). That dc voltage which must be applied between the input terminals through two equal resistances to force the quiescent dc output to zero or other specified level V_{QO} , generated by V_{QI} .

1.1.2 Input offset voltage drift (DV_{IO}). Input offset voltage drift is the ratio of the change of input offset voltage to the change of the circuit temperature.

$$DV_{IO} = \frac{\Delta V_{IO}}{\Delta T}$$

1.1.3 Input offset current (I_{IO}). The input offset current is the difference between the input bias currents entering into the input terminals of a differential input amplifier required to force the output voltage to zero or other specified level (V_{QO}).

1.1.4 Input offset current drift (DI_{IO}). The input offset current drift is the ratio of the change of input offset current to the change of circuit temperature.

$$DI_{IO} = \frac{\Delta I_{IO}}{\Delta T}$$

1.1.5 Input bias current (I_{IB}). The input bias currents are the separate currents entering into the two input terminals of a balanced amplifier, specified as $+I_{IB}$ and $-I_{IB}$. The bias current in a single ended amplifier is defined as I_{IB} .

1.1.6 Input offset voltage adjust ($\pm V_{IO\ adj}$). Bias adjustment which produces maximum offset at the output.

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and an appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figures show the connections for the various test conditions. An op amp null loop test figure is also shown as an alternate test setup. R_2 shall be no larger than the nominal input impedance nor less than a value which will load the amplifier ($10 \times Z_{OUT}$). Let $R_2/R_1 = 100$ or $0.1 \times$ (open loop gain), whichever is smaller. Recommended stabilization and power supply decoupling circuitry shall be added. R_3 shall be no larger than the nominal input impedance. For methods using the null loop circuit, assume all switches (relays) normally closed.

3.1 Input offset voltage.

3.1.1 Differential input amplifier. The test setup is shown on figure 4001-1. Input offset voltage $V_{IO} = (R_1/R_2)(E_O - V_{QI})$. Switches S_1 and S_2 are closed for this test.

3.1.2 Single ended inverting amplifier. The test setup is shown on figure 4001-2. Input offset voltage $V_{IO} = (R_1/R_2)(E_O - V_{QI})$. Switch S is closed for this test.

3.1.3 Single ended noninverting amplifier. The test figure is shown on figure 4001-3. $V_{IO} = (R_1/R_2)(E_O - V_{QI})$. Switch S is closed for this test.

3.1.4 Differential input amplifier. This is an alternative method using the null loop circuit of figure 4001-4, in which all switches are closed. Set V_C to zero. Measure E_O . $V_{IO} = (R_1/R_2)(E_O)$.

3.2 Input offset current. This has a meaning for differential input amplifiers only.

3.2.1 Differential input amplifier. The test figure is shown on figure 4001-1. Measure E_{01} with S_1 and S_2 closed, measure E_{02} with S_1 and S_2 open.

$$I_{IO} = \frac{R_1}{R_2} \left(\frac{E_{01} - E_{02}}{R_3} \right)$$

3.2.2 Differential input amplifier using null loop. The test setup is shown on figure 4001-4, S_1 and S_4 are closed, set $V_C = 0$. Measure E_{01} as in 3.1.4. Open S_2 and S_3 and measure E_{02} .

$$I_{IO} = \frac{R_1}{R_2} \left(\frac{E_{02} - E_{01}}{R_3} \right)$$

3.3 Input bias current.

3.3.1 Differential input amplifier. The test figure is shown on figure 4001-1. Measure E_{01} with S_1 and S_2 closed, measure E_{02} with S_1 closed and S_2 open. Measure E_{03} with S_1 open and S_2 closed.

$$I_{IB+} = \frac{R_1}{R_2} \left(\frac{E_{01} - E_{02}}{R_3} \right)$$

$$I_{IB-} = \frac{R_1}{R_2} \left(\frac{E_{01} - E_{03}}{R_3} \right)$$

3.3.2 Single ended inverting amplifier. The test figure is shown on figure 4001-2. Measure E_{01} with S closed, measure E_{02} with S open.

$$I_{IB} = \frac{R_1}{R_2} \left(\frac{E_{01} - E_{02}}{R_3} \right)$$

3.3.3 Single ended noninverting amplifier. The test figure is shown on figure 4001-3. Measure E_{01} with S closed. Measure E_{02} with S open.

$$I_{IB} = \frac{R_1}{R_2} \left(\frac{E_{01} - E_{02}}{R_3} \right)$$

3.3.4 Differential input amplifier using null loop. The test setup is shown on figure 4001-4. Set V_C to zero with S_1 and S_4 closed. Measure E_{01} with S_2 closed and S_3 closed. Measure E_{02} with S_2 open and S_3 closed. Measure E_{03} with S_2 closed and S_3 open.

$$I_{IB+} = \frac{R_1}{R_2} \left(\frac{E_{03} - E_{01}}{R_3} \right)$$

$$I_{IB-} = \frac{R_1}{R_2} \left(\frac{E_{02} - E_{01}}{R_3} \right)$$

3.4 Input offset voltage drift. Measurement of V_{IO1} is made at temperature T_1 in accordance with 3.1 and a second measurement at T_2 of V_{IO2} is made at the second temperature.

$$DV_{IO} = \frac{V_{IO2} - V_{IO1}}{T_2 - T_1}$$

3.5 Input offset current drift. Measurement of I_{IO1} is made at temperature T_1 and I_{IO2} at temperature T_2 in accordance with 3.2.

$$DI_{IO} = \frac{I_{IO2} - I_{IO1}}{T_2 - T_1}$$

3.6 Adjustment for input offset voltage. Use the value of E_0 for 3.1.4. Measure E_{01} with the offset null voltage (V_{ON}) set to the positive extreme.

$$V_{IO Adj(+)} = (E_0 - E_{01}) \frac{R_1}{R_2}$$

Measure E_{02} with the offset null voltage (V_{ON}) set to the negative extreme:

$$V_{IO Adj(-)} = (E_0 - E_{02}) \frac{R_1}{R_2}$$

NOTE: V_{ON} may be implemented using a combination of resistors to obtain the proper voltage across the offset null terminals. This determination shall be based on the device under test (DUT) specifications.

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of R_1 , R_2 , and R_3 , R_4 , R_5 , R_L , and $\pm V_{CC}$ of the nulling amplifier.

- a. V_{IO} maximum.
- b. DV_{IO} maximum at specified temperature(s).
- c. I_{IO} maximum when applicable.
- d. DI_{IO} maximum, when applicable at specified temperature(s).
- e. I_{IB+} and I_{IB-} maximum at specified temperature(s).
- f. V_{Q1} and V_{QO} , when applicable, at specified temperature(s).
- g. $\pm V_{IO Adj}$ at specified temperature(s).
- h. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified operating temperature and at +25°C ambient.

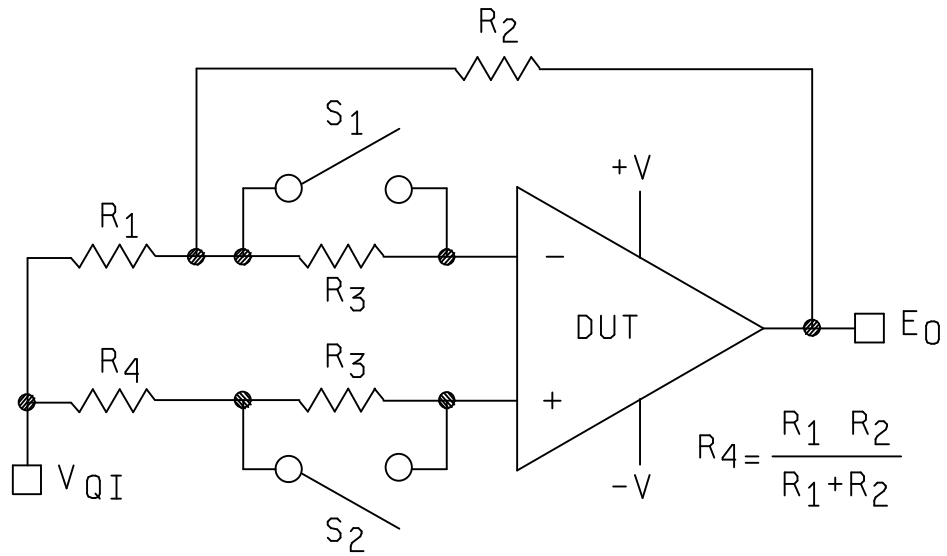


FIGURE 4001-1. Differential input amplifier.

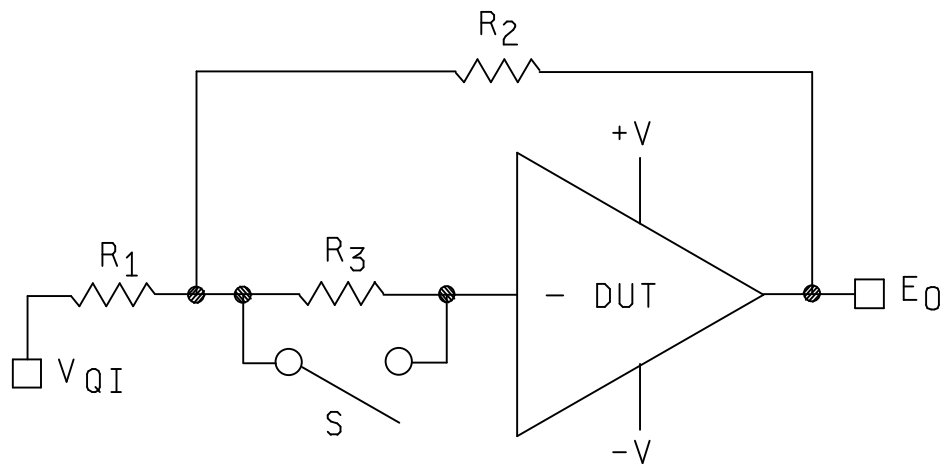


FIGURE 4001-2. Single ended inverting amplifier.

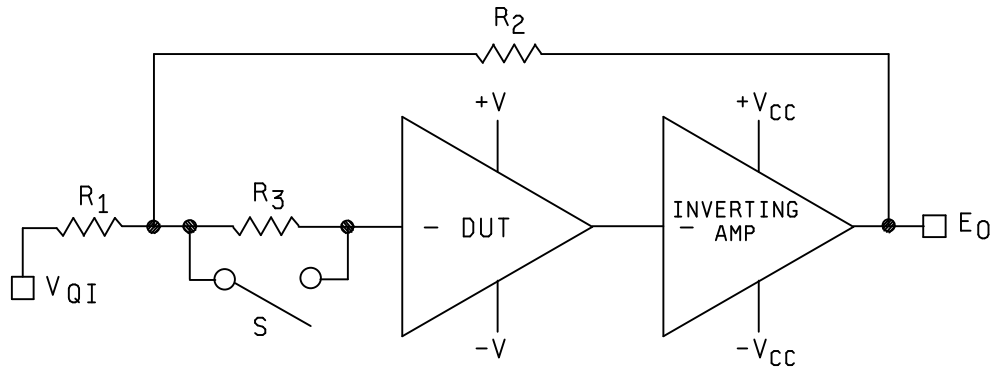


FIGURE 4001-3. Single ended noninverting amplifier.

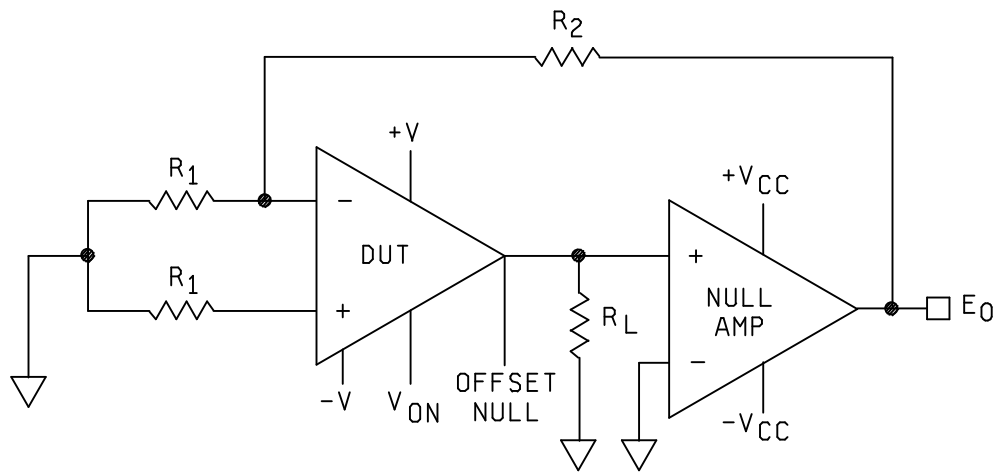


FIGURE 4001-4. Differential input amplifier using null loop.

METHOD 4002.1

PHASE MARGIN AND SLEW RATE MEASUREMENTS

1. PURPOSE. This method establishes the means for measuring the stability and slew rate of a linear amplifier intended to be used with feedback.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Phase margin. The phase margin is 180° minus the absolute value of the phase shift measured around the loop at that frequency at which the magnitude of the loop gain is unity. The loop is the series path of the device under test and the feedback network which is opened at the inverting terminal. The inverting terminal is loaded down to simulate the load normally presented by the feedback network. Good practice dictates that the phase margin should be at least 45° .

1.1.2 Peaking. If a closed loop gain versus frequency plot is made, peaking is the amount by which the gain may increase over its nominal value just before it falls off. 3 dB of peaking will result from a phase margin of 45° . Thus, it is desirable to keep the peaking less than 3 dB.

1.1.3 Slew rate. Slew rate is the time rate of change of the closed-loop amplifier output voltage under large signal conditions (i.e., the maximum ac input voltage for which the amplifier performance remains linear). Stabilization networks will affect the slew rate and therefore these must be included in the measurement.

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figures show the connections for the various test conditions. Recommended stabilization networks should be added to compensate for the degree of feedback in the test. The circuit under test should have adequate power supply decoupling added. For differential output devices, the measurements described in 3.1 through 3.2.1 below, as applicable, shall be repeated for the other output using the same test figure except an oscilloscope shall be connected to the other output.

3.1 Phase margin. The test shall be setup as on figure 4002-1 for a gain of 1 noninverting. This is the maximum feedback case. R_2 and R_1 shall be the same value and shall be low compared to the amplifier input impedance. Figure 4002-2 shows the amplitude of the envelope of the output E_0 . The peaking shall be less than 3 dB (1.414 times the flat band voltage) to indicate a 45° phase margin minimum. The circuit of figure 4002-3 shall be used for single ended inverting amplifiers (where no positive input terminal is brought out) or where the test is to be run at closed loop gains greater than 1. Closed loop gain = R_2/R_1 . In the case of closed loop gains greater than one, the peaking shall be less than 3 dB.

3.2 Pulsed slew rate. Figure 4002-1 or 4002-3 is the test figure for this test. Values of R_2 and R_1 shall be the same values as those used in the phase margin test. Stabilization networks shall also be the same. The pulse amplitude V_1 shall be such that E_0 is the maximum large signal value for the amplifier. With the pulse V_1 having a rise and fall time much faster than the specified slew rate for the amplifier, the rise and fall time for the amplifier shall be measured and shall be within specified limits (see 4). The test shall be repeated for both polarities of V_1 .

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of R_1 , R_2 , and V_1 .

- a. Maximum peaking.
- b. Maximum rise time for E_0 positive pulses.
- c. Maximum fall time for E_0 positive pulses.

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- d. Maximum rise time for E_0 negative pulses.
- e. Maximum fall time for E_0 negative pulses.
- f. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified ambient operating temperatures and at 25°C ambient.

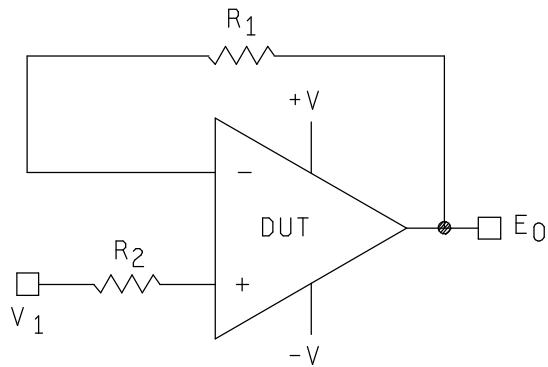


FIGURE 4002-1. Test setup noninverting amplifier.

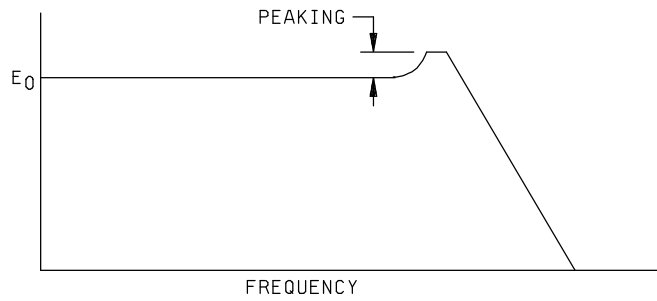


FIGURE 4002-2. Amplitude of E_o.

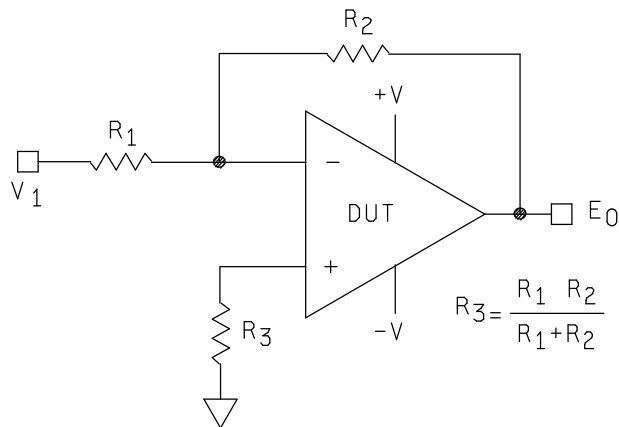


FIGURE 4002-3. Test setup single ended inverting amplifier.

METHOD 4003.1

COMMON MODE INPUT VOLTAGE RANGE
COMMON MODE REJECTION RATIO
SUPPLY VOLTAGE REJECTION RATIO

1. PURPOSE. This method establishes the means for measuring common mode input voltage range, common mode rejection ratio, and supply voltage rejection ratio.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Common mode input voltage range (V_{CM}). The common mode input voltage range is that range of common mode input voltages which, if exceeded, will cause the amplifier to distort or is that range of voltage which may be applied to the input terminals of the device without decreasing the common mode rejection ratio (CMRR) by more than 6 dB.

1.1.2 Common mode rejection ratio (CMRR). The common mode rejection ratio is the ratio of the differential open loop gain, A_D , to the common mode voltage gain, A_C .

$$CMRR = \frac{A_D}{A_C}$$

CMRR is usually expressed in decibels:

$$CMRR = 20 \log \frac{A_D}{A_C}$$

Common mode rejection ratio can also be expressed as the ratio of change in offset voltage to the change in common mode voltage.

$$CMRR = 20 \log \frac{\Delta V_{IO}}{\Delta V_{CM}}$$

1.1.3 Power supply rejection ratio (PSRR). The power supply rejection ratio is the ratio of the change in input offset voltage ΔV_{IO} , to the corresponding change in one power supply voltage with all remaining power supply voltage(s) held constant.

$$+ PSRR = \frac{\Delta V_{IO}}{\Delta V_{CC}} \quad V_{BB} = \text{constant}$$

$$- PSRR = \frac{\Delta V_{IO}}{\Delta V_{BB}} \quad V_{CC} = \text{constant}$$

$$PSRR = \frac{\Delta V_O}{A_D \Delta V_{CC}}$$

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and an appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figures show the connections for the various test conditions. Assume all switches normally closed. The feedback resistance, R_2 for figure 4003-1, shall be no larger than the nominal input impedance nor less than a value which will load the amplifier ($100 \times Z_{OUT}$). Specified stabilization and power supply decoupling shall be added where applicable.

3.1 Common mode input voltage range.

3.1.1 Differential input amplifier. This test shall be an implied measurement. The maximum common mode input voltage specified for the amplifier shall be used in making the common mode rejection ratio test of 3.2.

3.2 Common mode rejection ratio.

$$CMRR = \left| \frac{A_D}{A_C} \right|$$

where A_D = differential gain, and A_C = common-mode gain.

3.2.1 Differential input amplifier using null loop. The test figure is shown on figure 4003-1, all switches are closed. Raise V_+ , V_- , and V_C to V_{CM} volts above nominal (i.e., if $V_+ = 15$, $V_- = -15$, $V_C = 0$, $V_{CM} = 10$, then set $V_+ = 25$, $V_- = -5$, and $V_C = 10$). Measure E_{01} . Lower V_+ , V_- , and V_C to V_{CM} volts below nominal. Measure E_{02} .

$$CMRR = 20 \log \frac{R_1}{R_2} \frac{(E_{01} - E_{02})}{\Delta V_{CM}}$$

3.3 Power supply rejection ratio.

3.3.1 Differential input amplifier. The power supply shall be adjusted for a value equal to the average of the maximum and minimum allowable supply voltage. The signal generator connected to the power supply under test shall be adjusted such that the voltage input at the amplifier under test swings between maximum and minimum specified values. Then:

$$PSRR = 20 \log \frac{R_1}{R_2} \frac{(\Delta V_o)}{\Delta V_{CC}}$$

where: ΔV_o = Change in output voltage (peak)

ΔV_{CC} = Change in supply voltage (peak)

The frequency used shall be as specified.

3.3.2 Differential input amplifier using null loop. The test figure is shown on figure 4003-1. Set V_C to zero. For +PSRR set V_- to constant voltage and set V_+ to minimum value and measure E_{01} ; set the V_+ supplies to maximum values and measure E_{02} .

$$+ PSRR = 20 \log \frac{R_1}{R_2} \frac{(E_{02} - E_{01})}{DV_{CC}}$$

where DV_{CC} is the total change in power supply voltage (if the supplies vary from +5 to +20 V, $DV_{CC} = 20 - 5 = 15$ V). For -PSRR repeat the above measures with V_+ supply held constant and V_- varied between the minimum and the maximum value, measure E_{03} and E_{04} respectively.

$$- PSRR = 20 \log \frac{R_1}{R_2} \frac{(E_{04} - E_{03})}{DV_{CC}}$$

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4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of C_1 , C_2 , R_1 , R_2 , R_L , and $\pm V_{CC}$ for the nulling amplifier.

- a. V_{CM} at specified temperature(s).
- b. CMRR at specified temperature(s). V_i signal frequency when applicable.
- c. PSRR, when applicable, at specified temperature(s).
- d. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified ambient operating temperature and at 25°C ambient.

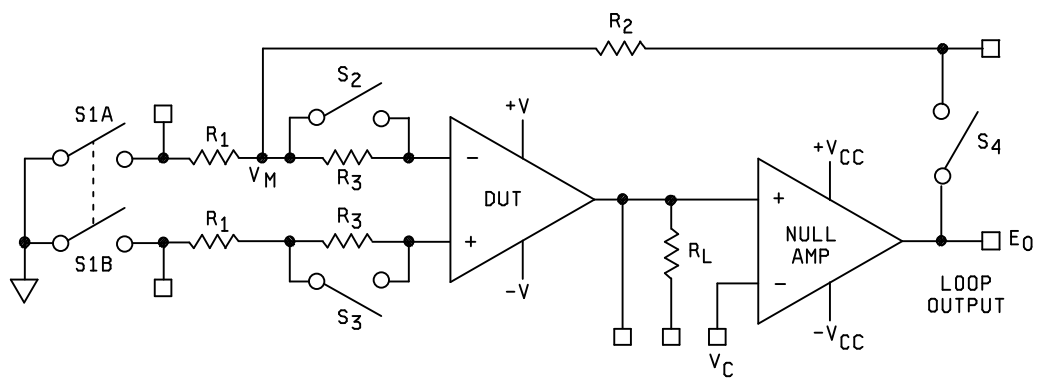


FIGURE 4003-1. Differential input amplifier using null loop.

METHOD 4004.1

OPEN LOOP PERFORMANCE

1. PURPOSE. The purpose of this test procedure is to measure gain, bandwidth, distortion, dynamic range, and input impedance. Gain, dynamic range, and distortion are combined into a large signal test where the distortion measurement will indicate either lack of dynamic range or inherent distortion.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Maximum output voltage swing (V_{OP}). The maximum output voltage swing is the maximum peak-to-peak output voltage which can be obtained without waveform clipping when the quiescent dc output voltage is set at a specified reference level. The swing levels are denoted by $+V_{OP}$ and $-V_{OP}$.

1.1.2 Single ended input impedance (Z_{IN}). The single ended input impedance is the ratio of the change in input voltage to the change in input current seen between either input and ground with the other input terminal ac grounded. In case of single input amplifiers, it is the impedance between that terminal and ground. It is measured at the quiescent output dc level.

1.1.3 Differential input impedance (Z_{DI}). The differential input impedance is the ratio of the change in input voltage to the change in input current seen between the two ungrounded input terminals of the amplifier at the quiescent output dc level.

1.1.4 Voltage gain (A_{VS}). The voltage gain (open loop) is the ratio of the output voltage swing to the single ended or differential input voltage, required to drive the output to either swing limit.

1.1.5 Bandwidth, open loop (BW_{01}). The open loop bandwidth is the range of frequencies within which the open-loop voltage gain of the amplifier is not more than 3 dB below the value of the midband open loop gain.

1.1.6 Distortion. The total ratio of the RMS sum of all harmonics to the total RMS voltage at the output for a pure sine wave input.

1.1.7 Unity gain bandwidth (GBW): The unity gain bandwidth is the frequency at which the output voltage is equal to the input voltage.

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and an appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figures show the connections for the various test conditions. A differential input is shown, but if a single ended inverting amplifier is under test, the components shown at the positive input terminal shall not be used. If a noninverting amplifier is under test, it shall be necessary to either use fixed bias instead of the dc feedback or to use an inverting gain of one amplifier in the feedback path. For differential output devices, the measurements described in 3.1, 3.2, 3.3, and 3.4 below, as applicable, shall be repeated for the other output using the same test figure except that the measuring equipment shall be connected to the other output.

3.1 Open loop gain using the null loop. The test figure is shown on figure 4004-3. The load resistor R_L is grounded. Set V_C to -10 V and measure E_{01} . Set V_C to +10 V and measure E_{02} .

$$A_{VS} = \frac{R_2}{R_1} \frac{20}{E_{02} - E_{01}}$$

3.2 Distortion. Under the conditions of 3.1, read the distortion on the distortion meter or the voltage at the output of the rejection filter if that is used.

3.3 Maximum output voltage swing. The test figure is shown on figure 4004-3. Set V_C equal to zero. Switches $S_1 - S_4$ are closed. For $+V_{OP}$ apply a V_1 equal to the positive supply voltage $+V_{OP} = V_2$. For $-V_{OP}$ apply a V_1 equal to the negative supply voltage $-V_{OP} = V_2$.

3.4 Bandwidth. Establish the amplitude of V_2 within the linear region of the device under test at a frequency specified for the measurement of A_D . Increase the frequency, while maintaining the amplifier of V_1 constant, until V_2 reduces to 0.707 of the original value (3 dB down). This frequency shall be measured as the bandwidth for the device under test. The test figure is shown on figure 4004-1.

3.5 Input impedance. This will be specified as a minimum value and shall be measured by observing that the output voltage V_2 does not drop more than 6 dB (2:1 in voltage) when the switch S is opened. This test shall be performed at the specified frequency with a specific amplitude of V_2 within the linear region. R_2 shall be given as the value of the minimum input impedance. The test figure is shown on figure 4004-1.

3.6 Unity gain bandwidth. Increase the frequency of e_1 (starting at 100 kHz) until $e_0 = e_1$. The frequency at which this occurs is GBW. The test figure is shown on figure 4004-4. Set the input voltage V_1 to the required device voltage.

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of R_1 , R_2 , C , $\pm V_{CC}$ for the nulling amplifier, R_3 and R_L .

- a. V_{OP} , at specified temperature(s).
- b. Z_{IN} (minimum), at specified temperature(s) and frequency.
- c. Z_{DI} , where applicable, at specified temperature(s) and frequency.
- d. A_{VS} , where applicable, at specified temperature(s) and frequency.
- e. A_V , at specified temperature(s) and frequency.
- f. BW_{01} , at specified temperature(s).
- g. Distortion (%), at specified temperature(s).
- h. V_{OI} , when applicable, at specified temperature(s).
- i. GBW, at specified temperatures.
- j. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified ambient operating temperatures and at 25°C ambient.

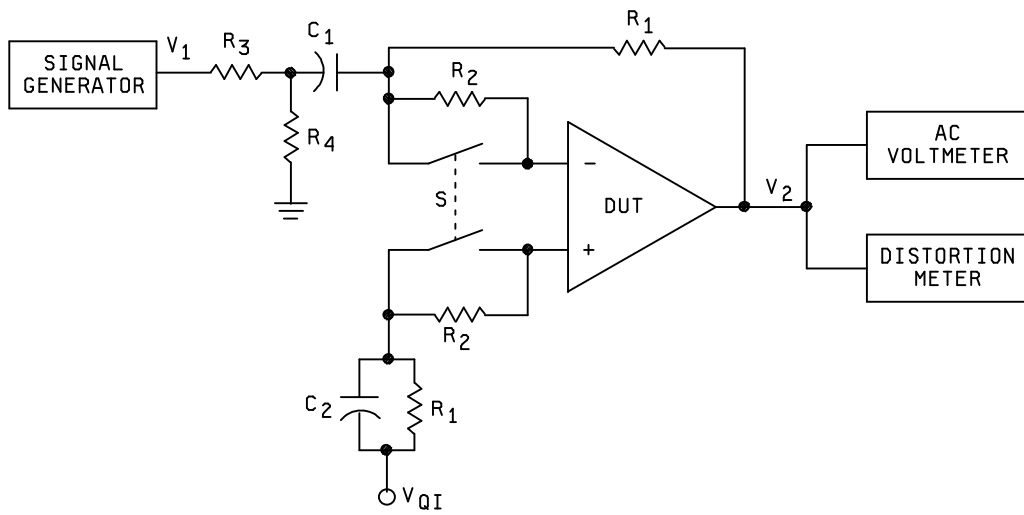


FIGURE 4004-1. Test figure for bandwidth and input impedance.

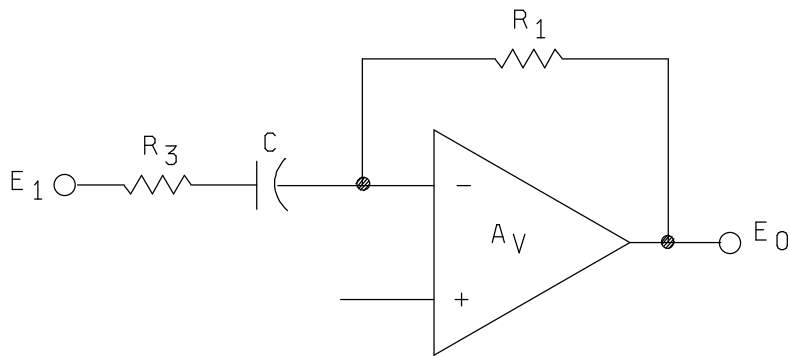


FIGURE 4004-2. Transfer function circuit.

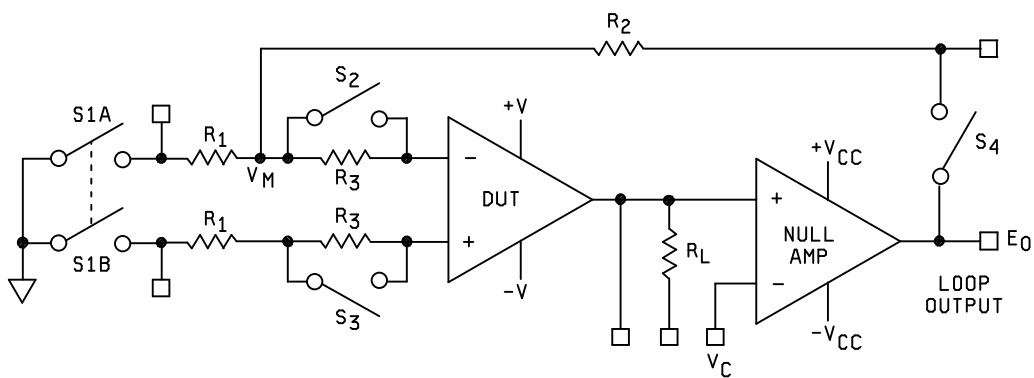


FIGURE 4004-3. Test setup for open loop gain, distortion and maximum output voltage swing.

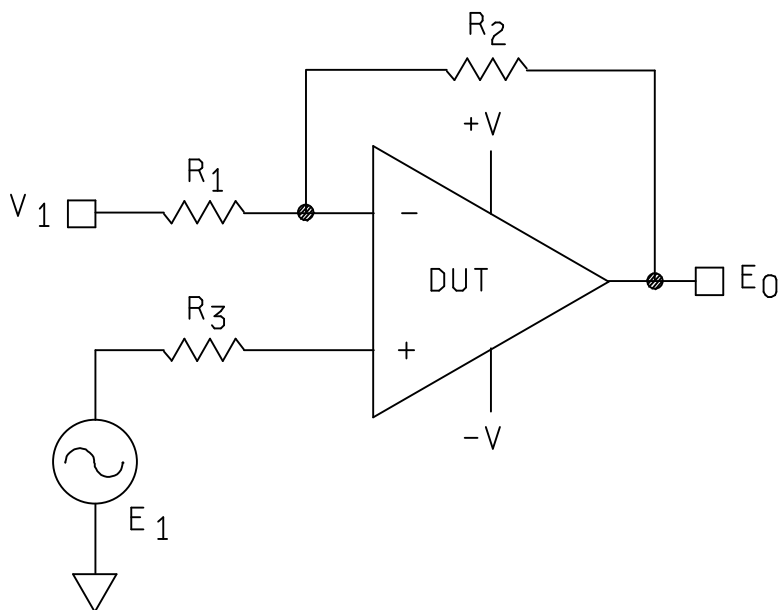


FIGURE 4004-4. Test setup for unity gain bandwidth.

METHOD 4005.1

OUTPUT PERFORMANCE

1. PURPOSE. This method establishes the means for measuring the power dissipation and output impedance.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Output impedance (Z_0). The output impedance is the impedance between the output terminal and ground. It is measured at a specific quiescent dc output voltage and with no ac feedback around the amplifier.

1.1.2 Power dissipation (P_D). The power dissipation is the total power dissipated in the amplifier with the amplifier biased into its normal operating range and without any output load.

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and an appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figure shown will be used for all three tests. R_1 should be no larger than the nominal input impedance nor less than a value which will load the amplifier ($100 \times Z_{OUT}$). $2 \pi f R_1 C_1$ shall be at least $10 A_D$ where A_D is the open loop gain and f is the test frequency. C_2 should be at least $10/2 \pi f R_2$ and R_2 should be about equal to the nominal amplifier Z_0 .

3.1 Power dissipation. For this test, the signal generator is off. Measure the positive supply voltage and current V_{CC} and I_C and the negative supply voltage and current V_{EE} and I_E . The power dissipation $P_D = V_{CC} I_C + V_{EE} I_E$.

3.2 Output impedance. For this test, the signal generator frequency is set to a specified value and the level is set to a specified V_2 . V_0 is read on the ac voltmeter. The output impedance is then equal to:

$$Z_0 = \frac{V_0 R_2}{V_2 - V_0}$$

An alternate measurement would be to make R_2 equal to the maximum acceptable value of Z_0 and require that V_0 be no greater than $V_2/2$. For differential output devices, this measurement shall be repeated for the other output using the same test figure except that the measuring equipment shall be connected to the other output.

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of R_1 , R_2 , C_1 , and C_2 .

- a. Z_0 limits at the specified frequency.
- b. P_D maximum.
- c. V_2 where applicable.
- d. V_{OI} where applicable at the specified temperature(s).
- e. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified operating temperature and at 25°C ambient.

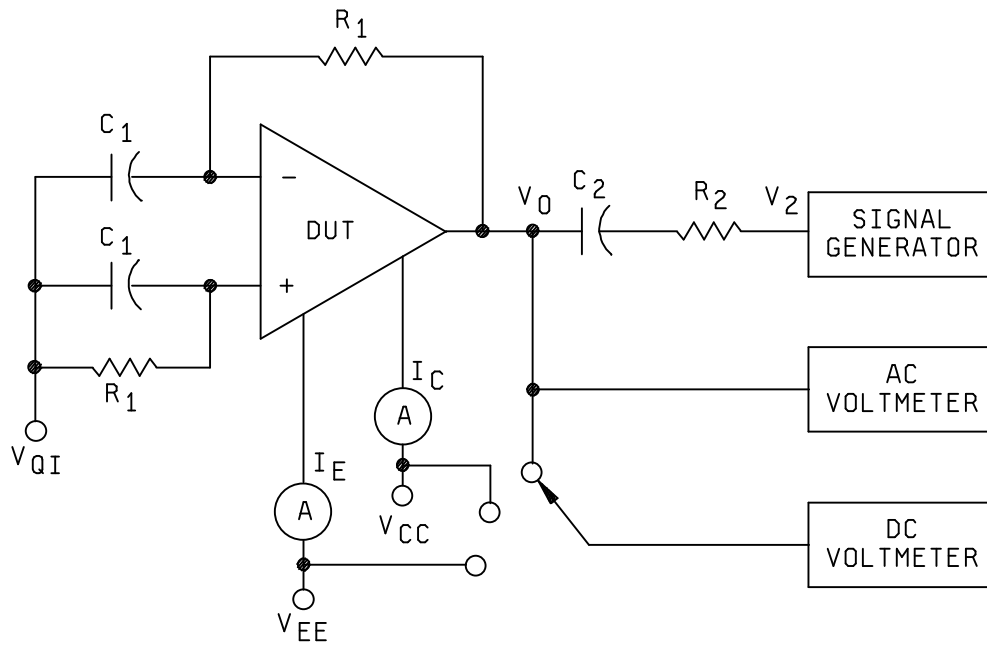


FIGURE 4005-1. Test setup-output performance.

POWER GAIN AND NOISE FIGURE

1. PURPOSE. The purpose of this test procedure is to measure small signal power gain and the noise figure of an amplifier.

1.1. Definition. The following definitions shall apply for the purpose of this test method.

1.1.1 Power gain (PG). The power gain is the ratio, expressed in dB, of the signal power developed at the output of the amplifier to the signal power applied to the input.

$$PG = 10 \log \frac{P_{OUT}}{P_{IN}}$$

1.1.2 Noise factor (F). The noise factor is the ratio of the signal-to-noise power ratio at the input to the signal-to-noise power ratio at the output.

$$F = \frac{\frac{P_{IN}}{N_{PIN}}}{\frac{P_{OUT}}{N_{POUT}}}$$

Where: P_{IN} = input signal power

P_{OUT} = output signal power

N_{PIN} = input noise power

N_{POUT} = output noise power

1.1.3 Noise figure (NF). The noise figure (NF) is the noise factor (F) expressed in dB.

$$NF = 10 \log F = 10 \log \frac{P_{IN} / N_{PIN}}{P_{OUT} / N_{POUT}}$$

The above expression for NF can be written in terms of voltage since the signal and its associated noise work into the same load.

$$NF = 20 \log \frac{\frac{V_{IN}}{N_{IN}}}{\frac{V_{OUT}}{N_{OUT}}} = 20 \log \frac{V_{IN}}{N_{IN}} - 20 \log \frac{V_{OUT}}{N_{OUT}}$$

Where: V_{IN} = signal voltage IN

V_{OUT} = signal voltage OUT

N_{IN} = noise voltage IN

N_{OUT} = noise voltage OUT

2. APPARATUS. The apparatus shall consist of appropriate test equipment capable of measuring specified parameters and an appropriate test fixture with standard input, output, and feedback resistances.

3. PROCEDURE. The test figures show the connections for the various test conditions. The signal frequency, where applicable, shall be a specified value within the defined bandwidth of the amplifier.

3.1 Power gain. Figure 4006-1 is used for this test. Unless otherwise specified, R_2 shall be equal to the nominal output impedance of the device under test. If the input resistance (R_i) of the device under test is much greater than the source resistance (R_G), unless otherwise specified, a resistor (R) which makes $V_1 = 1/2 V_G$ should be added in series with R_G . The specified ac signal V_G at the specified frequency is applied to the inputs of the amplifier under test. V_1 and V_L are recorded. Then:

$$PG(db) = 10 \log \frac{V_L^2}{V_1 (V_G - V_1)} \times \frac{R_G}{R_2}$$

If the series resistor (R) has been added, then:

$$PG(db) = 10 \log \frac{V_L^2}{V_1 (V_G - V_1)} \times \frac{R_G'}{R_2}$$

where: $R_G' = R_G + R$

3.2 Power gain (insertion method). If the input resistance (R_i) to the device under test is known, the power gain can be measured by this procedure. On figure 4006-2 with switch S in position 1, and the attenuator set to zero insertion loss, a reference level is established on the oscilloscope. The switch is then moved to position 2, switching in the circuit under test, and the attenuation increased until the output is brought to the previous reference level. The voltage insertion gain of the circuit under test equals attenuator setting in dB. The power gain is then calculated from the following expression:

$$PG(dB) = (\text{Attenuator reading}) + 20 \log \frac{R_i (R_G + R_2)}{R_2 (R_G + R_i)}$$

where: R_2 equals the nominal output impedance of the circuit under test.

R_G equals the source resistance.

R_i equals the input impedance of the circuit under test, unless otherwise specified.

The accuracy of this measurement is dependent upon the accuracy of the attenuator.

3.3. Noise figure. Figure 4006-3 is used for this test. The input noise voltage shall be calculated from the following expression:

$$N_{IN} = \sqrt{4KT\Delta f \pm R_G}$$

where: K = Boltzmann's constant (1.38×10^{-23} joules/°K)
 T = Temperature (°K)
 Δf = Noise bandwidth
 R_G = Source resistance

The input signal level is then set to ten times (20 dB) N_{IN} . R_X is now adjusted so that the ac voltmeter reads 10 dB on some convenient scale. The input signal V_G is then reduced to zero and the reduction in dB on the output recorded. The noise figure NF is obtained by subtracting this drop in dB from 20 dB. The error in this measurement can be calculated from the following expression:

$$Error (dB) = 10 \log \left[\left(\frac{V_{OUT}}{N_{OUT}} \right)^2 + 1 \right] - 20 \log \frac{V_{OUT}}{N_{OUT}}$$

It should be noted that the error will always be in a direction to indicate a lower noise figure than the true noise figure.

3.4 Noise figure, alternate method. In this test, a diode noise generator, as shown on figure 4006-4, is used to measure the noise figure. In this test, with switches S_1 and S_2 in position 1 and the source resistance (R_S) adjusted to a specified value, a reference voltage is read on the ac voltmeter. The switches S_1 and S_2 are then moved to position 2 and the diode source current (I) increased until the previous reference level is read on the ac voltmeter. Using the value of I and R_S , the noise figure is determined for the following expression:

$$NF = 10 \text{ Log } 20 IR_S$$

The accuracy of this technique is established by the accuracy of the 3 dB pad and the current meter in the noise diode circuit.

3.5 Noise factor. The noise factor can be determined from the following expression:

$$NF = 10 \text{ Log } F$$

In this expression, NF is in dB and F is a numeric.

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of R_2 and R_G :

- a. PG, at specified temperature(s) and frequency, and R_2 .
- b. NF, at specified temperature(s) and frequency.
- c. F, at specified temperature(s) and frequency.
- d. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified ambient operating temperatures and at 25°C ambient.
- e. Noise bandwidth (Δf) (see 3.3).
- f. R_S (see 3.4).
- g. R and R_2 , when applicable (see 3.1).

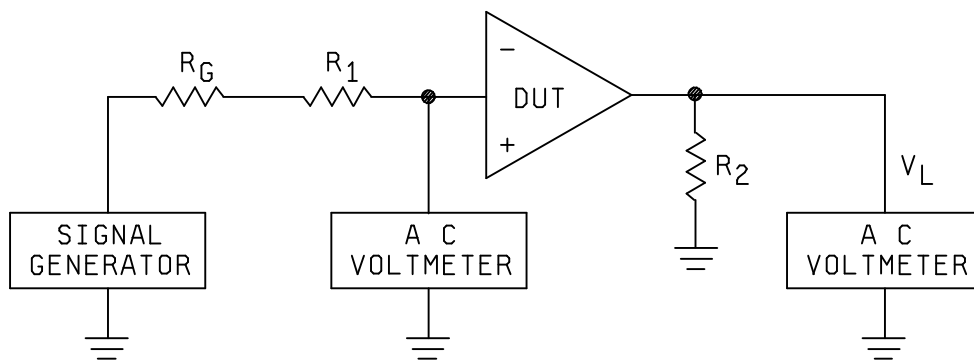


FIGURE 4006-1. Power gain test circuit.

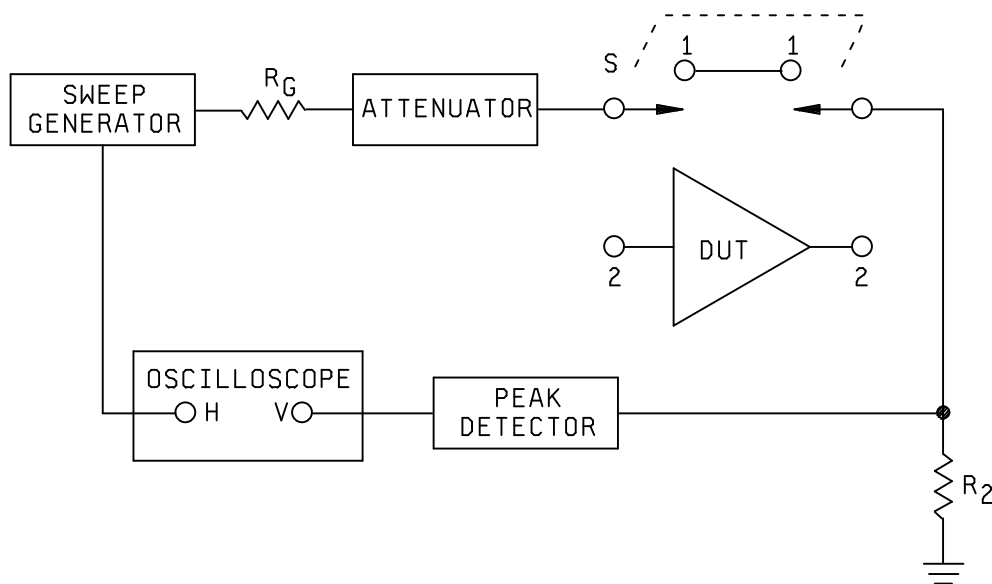


FIGURE 4006-2. Power gain test circuit (insertion method).

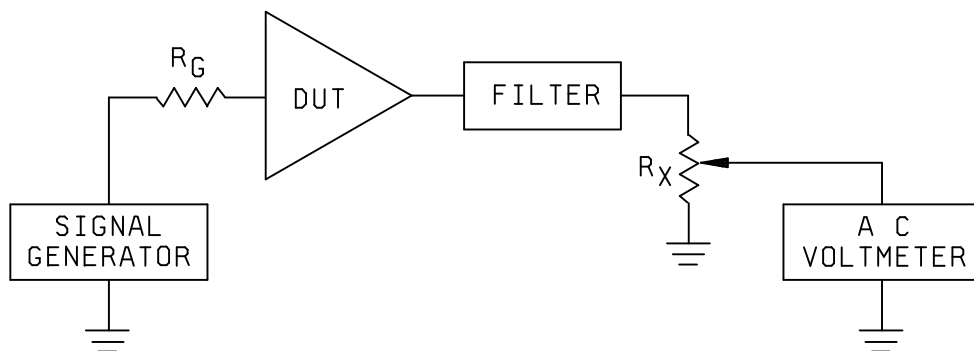


FIGURE 4006-3. Noise figure test circuit.

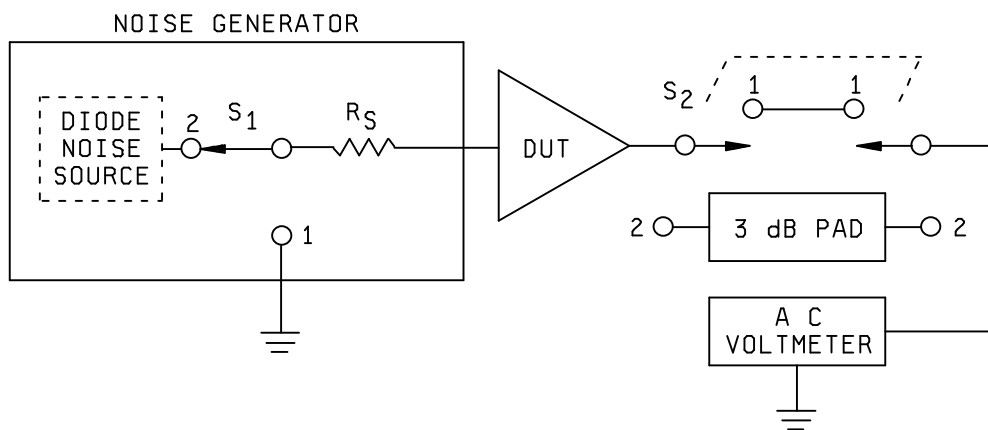


FIGURE 4006-4. Noise figure (double power technique).

METHOD 4007

AUTOMATIC GAIN CONTROL RANGE

1. PURPOSE. This method establishes the means for measuring the automatic gain control range of a linear amplifier.

1.1 Definitions. The following definition shall apply for the purpose of this test method.

1.1.1 Automatic gain control range (AGC). The AGC range is the total change in voltage gain which may be achieved by application of a specified range of dc voltages to the AGC input terminal of the device.

$$AGC = 20 \log \frac{A_v \text{ max}}{A_v \text{ min}}$$

2. APPARATUS. The apparatus shall consist of a sweep generator, voltage source, resistors, capacitors, an ac voltmeter, and a distortion analyzer.

2.1 Sweep generator. The sweep generator must cover the frequency range of the amplifier under test. It shall have an adjustable output level which is flat over the sweep range. It shall be capable of single frequency operation.

2.2 Voltage source. The voltage source shall be capable of supplying the specified AGC voltages to the test circuit. The voltage source shall be free of noise or ripple at its outputs.

2.3 Capacitors and resistors. The capacitors and resistors shall be within 1 per cent or better of the specified values and stable over the test temperature range.

2.4 AC voltmeter. The ac voltmeter shall be capable of measuring the amplifier output voltage without loading and shall have a frequency range that will cover the amplifier under test.

2.5 Distortion analyzer. The distortion analyzer or meter shall be usable over the passband of the amplifier and shall not load the amplifier.

3. PROCEDURE. The test circuit shown on figure 4007-1 shall be used for this test. R_L and C_1 shall be selected to properly load and decouple the circuit, respectively. The AGC voltage is set for maximum gain. The input signal is applied (constant frequency) and increased until the output exhibits maximum allowable distortion. The generator is swept over the prescribed range and the bandwidth noted.

The AGC voltage is varied over the specified range and the reduction in gain is measured. The above measurements are repeated and the bandwidth and signal handling capability recorded.

4. SUMMARY. The following details shall be specified in the applicable acquisition document for specified values of C_1 and R_L .

- a. AGC range.
- b. Test frequency range.
- c. Increase in bandwidth over the AGC range.
- d. Maximum reduction in output impedance, where applicable.
- e. Minimum reduction in input signal capability, where applicable.
- f. Any other variations when applicable, such as power variation, overloading, limitations as to linearity of gain response versus AGC voltage, etc.
- g. Test temperature(s). Unless otherwise specified, all parameters shall be measured at the minimum and maximum specified ambient operating temperature and at 25°C ambient.

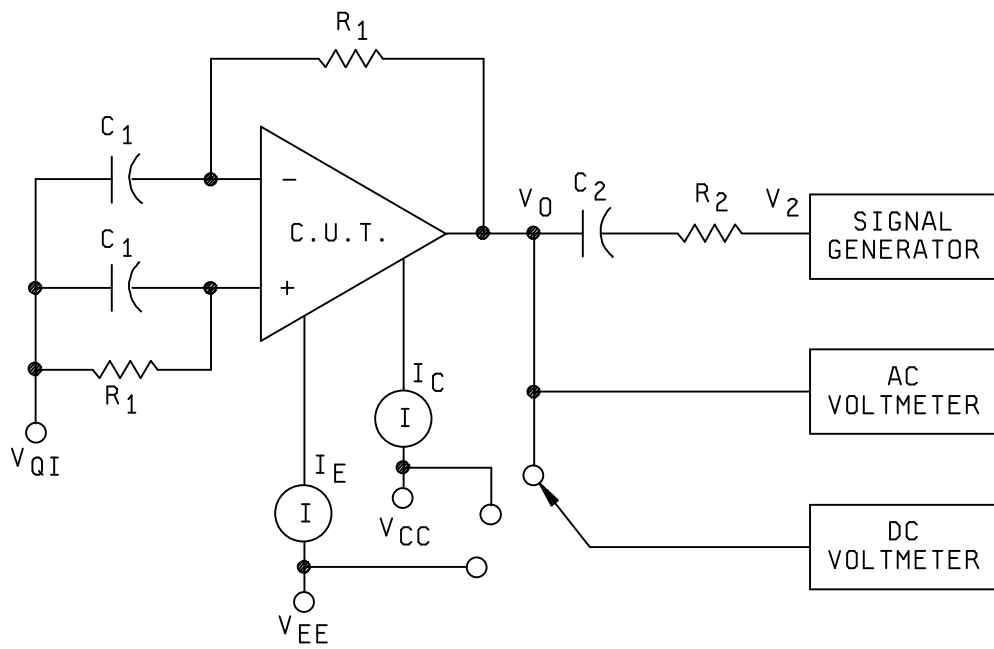


FIGURE 4007-1. AGC test circuit.