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Ground and V_{CC} Bounce of High-Speed Integrated Circuits AN223

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INTRODUCTION

The purpose of this paper is to give a general description of what ground and V_{CC} bounce are, why it is they are tested, and a detailed description of how they are tested.

WHY SHOULD GROUND AND V_{CC} BOUNCE BE TESTED?

Ground and V_{CC} bounce testing is done to evaluate what effect switching more than one output simultaneously has on the performance of the integrated circuit. This effect becomes important in any high-performance line of circuits because the propagation delays and output edge rates are very fast. This can cause ground bounce and V_{CC} bounce, described as Voltage Output Low Peak (V_{OLP}) and Voltage Output High Valley (V_{OHV}), respectively.

Fast edge rates of the output drivers can team up with internal parasitic lead inductance and the output load to produce unwanted side effects of noise on the outputs. This noise or ringing will occur on both a static and a switching output. This ringing can be substantial enough to cross the input triggering threshold of a subsequent device, which in turn can cause a system to perform unpredictably and unreliably.

GENERAL CONSIDERATIONS

There are two factors to consider when testing ground and V_{CC} bounce: the test fixture and test methods. Both are of equal importance for accuracy, repeatability, and correlation.

These tests determine the magnitude of the peaks and valleys on the low and high static output levels during multiple output switching. V_{OHV} refers to the minimum voltage "valley" on an output in the high level state. V_{OLP} refers to the maximum voltage "peak" on an output in the low level state. Figure 1 shows a typical example of what V_{OLP} and V_{OHV} look like, and also defines the points where V_{OLP} and V_{OHV} are measured.

For circuits with a single output or a single complementary output, the circuit is set up so that the pin under test is switching and the V_{OLP} and V_{OHV} levels are then measured at the points on the waveform as shown in Figure 1.

The most accurate way to determine the actual voltage dropped across the package lead inductance is to measure the magnitude of the ringing while the tested output is in the steady state. To evaluate the worst case, the V_{CC} should be at the maximum operating range, usually 5.5V, which will produce the highest V_{OH} levels. The higher V_{OH} level will create more dynamic switching current to flow through the lead inductance and produce a larger voltage ring on the outputs.

For further information see references.

GROUND BOUNCE METHOD

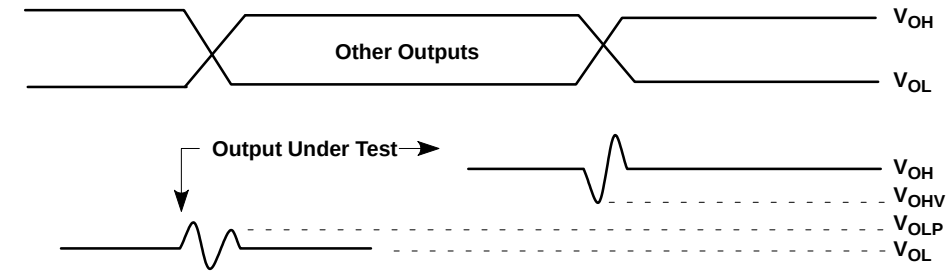
V_{OLP} is usually evaluated on the output pin furthest from the ground pin with the longest package lead length. The static output is in the low state and the switching outputs going from high to low. Examine the waveform and record the level of V_{OLP} as defined by Figure 1.

V_{OLP} should not be evaluated on the output adjacent to the ground pin. Mutual lead inductance will effectively reduce the magnitude of the output ringing by a factor of two.

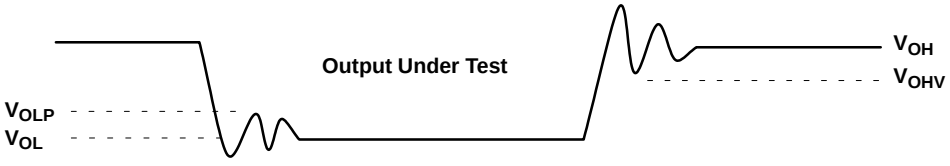
V_{CC} BOUNCE METHOD

V_{OHV} is usually evaluated on the output pin furthest from the V_{CC} pin with the longest package lead length. The static output is in the high state and the switching outputs going from low to high. Examine the waveform and record the level of V_{OHV} as defined by Figure 1.

V_{OHV} should not be evaluated on the output adjacent to the ground pin. Mutual lead inductance will effectively reduce the magnitude of the output ringing by a factor of two.



V_{OLP} and V_{OHV} for Circuits with Multiple Outputs



V_{OLP} and V_{OHV} for Circuits with Single or Complementary Outputs

Figure 1. Test Waveforms

Ground and V_{CC} Bounce of High-Speed Integrated Circuits AN223

V_{OLP} VS. V_{IN} METHOD

Set up the V_{OLP} test and sweep the static input from 0.0V to 1.5V in 100mV increments, taking measurements at each point. Comparison data can be taken on a variety of ICs using the same set-up and test fixture. Plotting this data in graph form will show how the ICs compare with each other for input noise sensitivity during simultaneous switching. The same test can be performed on V_{CC} bounce.

TEST FIXTURES AND SET UP PROCEDURES

Refer to Table 1 for a complete list of test equipment and hardware. The test fixture will be the same one used for standard AC testing. This is a high-frequency PC board fixture featuring adequate internal ground and V_{CC} planes as well as 50Ω micro strip line for all signal paths and close proximity loading. The test fixture should have V_{CC} decoupling of at least 100µF, 0.1µF, 0.01µF and 1000pF. For a complete discussion of fixturing requirements including grounding, bypassing and general high-frequency testing requirements refer to the Application Note entitled “Testing and Specifying FAST Logic” (FAST Data Manual: AN202) and “Printed Circuit Board Test Fixtures for High-Speed Logic” (ABT Data Manual: AN602).

Pulse Generator Set Up

(Refer to “Test Circuit and Waveforms” in the appropriate data book for voltage levels and edge rates.)

Voltage levels: V_{IH}=3.0V, V_{IL}=0.0V
Threshold voltage levels: V_{IH}=2.5V, V_{IL}=0.5V
Rise and fall times: (t_R/t_F) = 2.5ns (10% to 90%)
Frequency: 1MHz @ 50% duty cycle
The pulse generator should be set up to provide simultaneous switching of the input signals. (“Simultaneous” is defined as all the input pins of the device seeing a given signal at the same moment in time.)

The preferred method is to drive each input with a separate pulse generator channel. Each input signal should be terminated with 50Ω resistor as close to the input pin as possible. The Tektronix HFS9009 data generator provides channel delays with 1ps resolution on the edge placement accuracy. The input skew from channel to channel should be set up with a maximum limit of ±50ps, but the target is less than ±30ps. The greater the input skew is, the worse the correlation will be. For example, using ±100ps produces about 50mV error (5%) for V_{OLP} and ±250ps produces about 100mV error (10%) for V_{OLP}. Therefore, it becomes very important to use a tight input skew to produce accurate and repeatable data.

The second method is to use a ganged type configuration, where one pulse generator signal is used to drive all inputs. This method is employed when the number of device inputs exceeds the number of pulse generator channels. The input signal should be terminated with 50Ω and then branched out equally to all inputs needing the input signal. Line lengths from the termination to the device pin should be kept as short as possible and of equal lengths. The input edge rates should be as close as possible to the data manual specifications.

General Set Up

All outputs should be loaded with the standard 50pF, 500Ω AC load.

When applicable, plots should be taken on at least one part and data values should be taken on three parts. The one part used for plots should have typical characteristics for the sample as a whole.

V_{CC} BOUNCE TESTING

Voltage Output High Valley (V_{OHV})

Measure the V_{OHV} level on an output held high during simultaneous switching. (Non-storage type devices only.)

The output to be evaluated for V_{OHV} should be the pin farthest from the V_{CC} pin. If there are two equidistant pins, record data on both outputs and plot only the worst-case output. Also, if more than one mode/path exists, all should be checked, but only the worst case tested. The output should be evaluated on the Low to High transition of the switching outputs.

1. V_{CC} = 5.5V, Temp = –55°C and V_{CC} = 5.0V, Temp = 25°C
2. Three parts are tested and plots should be taken on one of the parts.
3. The input conditions should be set so that the output under test is a static high.
4. Switch the remaining outputs simultaneously from low to high and record V_{OHV}.
5. Plot waveforms of a switching input, the high output, and a switching output.

Repeat steps 4 through 5 for the following other modes:

- High to Low
- 3-State to Low (if possible)
- Low to 3-State (if possible)
- High to 3-State (if possible)
- 3-State to High (if possible)

GROUND BOUNCE TESTING

Voltage Output Low Peak (V_{OLP})

Measure the V_{OLP} level on an output held low during simultaneous switching. (Non-storage type devices only.)

Table 1. Equipment Requirements (Hardware)

DEVICE	CHARACTERISTICS	MODEL
Digital Oscilloscope	1GHz bandwidth, 50Ω channels and cables	TEK11402
Data Generator	36 channel, 1ps edge placement resolution	TEK HFS9009
Temperature Forcing Unit	-55°C to +125°C (Thermonics)	T2420
Power Supply	4 channel, 0V–20V @ 5A	HP6632A
Test Fixture	High frequency (900MHz); Controlled 50Ω impedance; Full ground and V_{CC} planes; Sufficient V_{CC} decoupling (Chip caps and Tantalum caps)	SIG SD8807.27

GROUND BOUNCE TESTING Voltage Output Low Peak (V_{OLP}) (CONTINUED)

The output to be evaluated for V_{OLP} should be the pin farthest from the Ground pin. If there are two equidistant pins, record data on both outputs and plot only the worst-case output. Also, if more than one mode/path exists, all should be checked, but only the worst case tested. The output should be evaluated on the High to Low transition of the switching outputs.

1. V_{CC} = 5.5V, Temp = –55°C
   V_{CC} = 5.0V, Temp = 25°C
2. Three parts are tested and plots should be taken on one of the parts.
3. The input conditions should be set so that the output under test is a static low.
4. Switch the remaining outputs simultaneously from high to low and record V_{OLP}.
5. Plot waveforms of a switching input, the low output, and a switching output.

Repeat steps 4 through 5 for the following other transitions:

- Low to High
- 3-State to Low (if possible)
- Low to 3-State (if possible)
- High to 3-State (if possible)
- 3-State to High (if possible)

NOISE IMMUNITY COMPARISON TESTING V_{OLP} VS. V_{IN}

Set up the V_{OLP} test and measure V_{OLP} while incriminating the static input voltage. (Non-storage type devices only).

The output to be evaluated for V_{OLP} should be the pin farthest from the ground pins. If there are two equidistant pins, record data on the worst-case output. Also, if more than one mode/path exists, all should be checked, but only the worst case tested. The output should be evaluated on the falling edge of the switching outputs.

1. V_{CC} = 5.5V, Temp = –55°C and
   V_{CC} = 5.0V, Temp = 25°C
2. One part of each variety to be tested.
3. Evaluate V_{OLP} while the other outputs switch simultaneously from high to low.
4. Increment V_{IN} on the static input from 0.0V to 1.5V in 100mV increments and record V_{OLP} at each increment. Graph data for all parts as V_{OLP} vs. V_{IN} (V_{IN} on X axis, and V_{OLP} on the Y axis). Use a power supply output to drive the static input.

As long as the testing set-up and the fixture are identical, this graph will show an accurate comparison of ground bounce sensitivity among the parts. (The same test can be performed on V_{OHV} by setting up the V_{OHV} test and sweeping the static input from 3.0V to 1.5V in 100mV increments.)

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