

High Speed Clock Sources and Their Effect on Electromagnetic Compatibility

National Semiconductor
Application Note 988
Behzad Bakshandeh
July 1995



System clocks of 100 MHz and above are becoming not uncommon in today's desktop personal systems. These higher speed personal computers will generate more unwanted noise due to their faster frequencies and edge rates.

This noise can be in many forms, but the most common one is EMI. EMI, ElectroMagnetic Interference can be defined as a form of noise pollution. This noise occurs when changes in electric fields which are created by the transitioning voltage signals combine with the magnetic field changes which are created by the changing current directions. This Electro-magnetic field can either be conducted via the printed circuit traces or even at the same time radiated through the board material and space to the outside world.

EMI is of interest to everyone. For this reason many governments and their agencies have issued specifications requiring compliance by all the electro, electro-mechanical and electronic equipment and their manufacturers. These specifications are to ensure that certain techniques are applied so that the products can interoperate in a common environment such that no degradation of performance would exist due to internally or externally conducted or radiated EM emissions. This is defined as the Electromagnetic Compatibility or simply the EMC.

National's Clock Generation and Support product family consists of clock drivers and generators which are designed to operate above 50 MHz. At such speeds, the use of these products requires many design consideration for noise reduction.

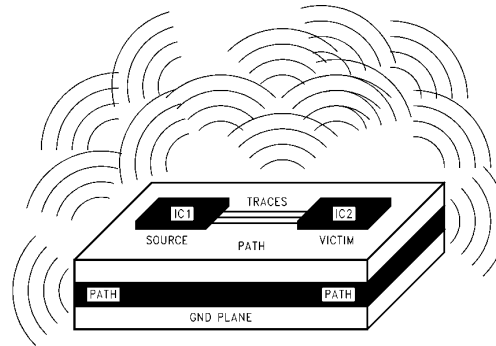
Below is a brief tutorial aimed at such purpose. In order to minimize and contain possible electromagnetic radiation one must first understand its causes and sources.

THE SOURCE, VICTIM AND THE COUPLING PATH THEORY:

This theory simply states that within each system there exists a source (typically a high frequency component) that generates the noise, and then there is a victim or receptor of the same high frequency signal or noise (*Figure 1*).

The coupling path can take two forms. If there is an actual connection between the source and the receptor this coupling path causes the interference to take a conductive form. A typical example would be ribbons, cables and traces. If the source and the receptor are separated by space and no physical connections exist between the two, then the interference takes the form of radiation.

In practice most systems have both forms of interference, conducted and radiated, and they co-exist at the same time.



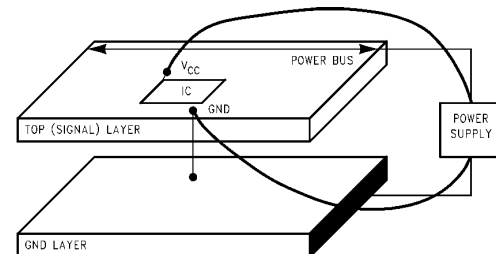
TL/F/12399-1

FIGURE 1. Source, Path and Receptor

This theory can also be looked at differently. EMI sources, paths and victims can be further separated into three categories within each system:

1. Power Plane/loop for all or individual components.

This consists of the power supply (receptor), power/ground planes and traces (paths) and components (sources). This loop can take the form of conducted interference since there exists an actual connection between the power pins of every component and the power supply via either power planes or power traces (*Figure 2*).



TL/F/12399-2

FIGURE 2. Power Distribution Loop

2. Signal paths.

These paths are typically signal traces or cables that are carrying high frequency signals throughout the board, either from point to point or in a bus fashion. The sources in this case are the drivers or their outputs, while the victims are the receivers or other components inputs. The path includes the termination network as well as signal traces.

High Speed Clock Sources and Their Effect on Electromagnetic Compatibility (Continued)

The EMI that is associated with these paths are both conducted and radiated. Conducted since there are actual connections between the sources and the receptors, while there will be radiation as well since there exists a decoupling path thru different layers and their mutual inductances to the power planes as well as outside of the enclosure.

Minimizing the coupled inductance between these paths helps to minimize the overall radiated noise from the system. The coupled loop area between the adjacent traces and characteristic impedance of the interconnect lines also play an important role in the overall level of the created noise.

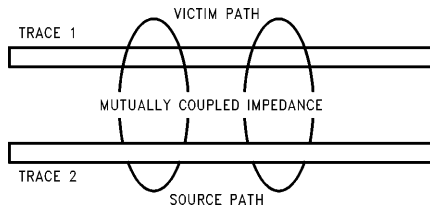


FIGURE 3. Signal Path

3. Package radiation.

This form of EMI can be caused within the high speed components which are radiating outside as well as within the system's enclosure itself. This form can be classified as radiated EMI.

In this case the sources or the emitters are internal to the components. This radiation is caused by electromagnetic wave propagation through space or material. This is the most important (least desired) form of EMI since it not only involves other equipments, but also is the most difficult one to contain.

Below are some recommendations that can help to minimize the electromagnetic interference. These suggestions are common practices during the device and board level system design. There are also some suggestions for decoupling the power planes and shielding the system.

DEVICE LEVEL RECOMMENDATIONS:

These recommendations need to be implemented during the chip level design. The primary task at this point is to design the components in a way that not only they meet the system's timing requirements, but also they produce the least amount of radiated and decoupled noise as well.

Figure 4 reflects a time domain translation of a trapezoidal signal to its frequency domain. In order to reduce any emissions both the amplitude and slopes of this signal must be minimized.

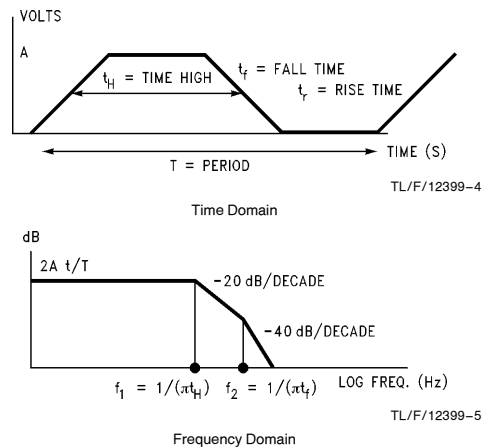


FIGURE 4. Time to Frequency Domain

As it is shown the frequency component of any signal can be represented by the amplitude, period, rise and fall time of the same signal in real time. Reducing the amplitude (i.e. from 5V to 3V signal swing) can reduce the total power associated with the signal, while slowing the edge rates helps to decrease the rate (slope) at which the energy is dissipated.

Here are some suggestions in order to accomplish such:

- Rounded-off edges contain less high frequency components
- Minimizing output voltage swing reduces noise. Low Voltage technologies such as TTL, LVDS and 3.3V supply will help to lower emissions.
- The edge rate must be as slow as they can be allowed without violating overall system timing.

BOARD LAYOUT RECOMMENDATIONS:

As the frequencies increase the parasitic effects of the printed circuit boards become more visible. Some common practice for minimizing such effects are listed below. Employing these guidelines can help to reduce the overall EMI levels. Figure 5 represents some of these suggestions.

- Multi-layer Printed Circuit board should be used.
- Wire-wraps should be avoided since they can act as antennas.
- Power and ground PLANES must be used instead of traces when possible.
- The effective distance between these planes should be as small as possible to increase the bulk decoupling capacitance.
- No sockets!
- Multi-via pads for power and ground pad connections can help to reduce the effective impedance.
- Trace lengths should be as short as possible.

High Speed Clock Sources and Their Effect on Electromagnetic Compatibility (Continued)

- If Analog sections exist, use of Islands for both the power and ground busses are preferred for Isolation techniques.
- High frequency signal traces must be sandwiched between ground traces or planes for minimizing cross talk.
- Avoid using sharp corners/bends on traces carrying high frequency signals.

POWER DISTRIBUTION DECOUPLING RECOMMENDATIONS:

One of the most susceptible victims of EMI is the power supply. This path (loop) includes the power supply, planes (V_{CC} and Ground) as well as the device power pins. Minimizing the size of this loop helps to reduce EMI since it helps to contain the noise in a smaller area.

- Bypass caps must be used, sometimes in multiples and should be as close as possible to the device V_{CC} pin and the ground plane.
- Bypassing must be done for ALL power pins.
- Multiple value bypass capacitors must be used in order to filter out the right analog V_{CC} will help to filter some high frequency noise components.
- Electrolytic capacitors are more preferred for decoupling.

SYSTEM LEVEL/GENERAL RECOMMENDATIONS:

And finally some suggestions to be observed throughout the whole system design. These suggestions, no matter how large the amount of noise, will help to contain the interferences within the system.

- Twisted pairs of Coax (rigid, semi-rigid or flexible) cable must be used for lines that can not be placed on the printed circuit board.
- All I/O cables must be shielded and tied to chassis ground with a low impedance connection.
- All the enclosure's opening must be minimized in number and size.
- Number of outputs that need to be switching simultaneously must be kept at minimum for reduced X-talk.
- Terminations must be used for minimizing reflections.

Summary and Conclusion:

In order to meet the Electromagnetic standards, many design guidelines and practices must be followed. These practices if done properly will help to minimize the level of the noise that is generated by the system.

In addition, it is preferred to spend the time and money prior to production commitment compared to a costly last minute fix to become EMI compliant.

References

1. Cocovich, Joe, EMI/RFI Board Design. National Semiconductor Application Note 643. Dec. 1989.
2. Gerke, Darryl & Kimmel, William. Designer's Guide to Electromagnetic compatibility. EDN Supplement Jan 20, 1994.

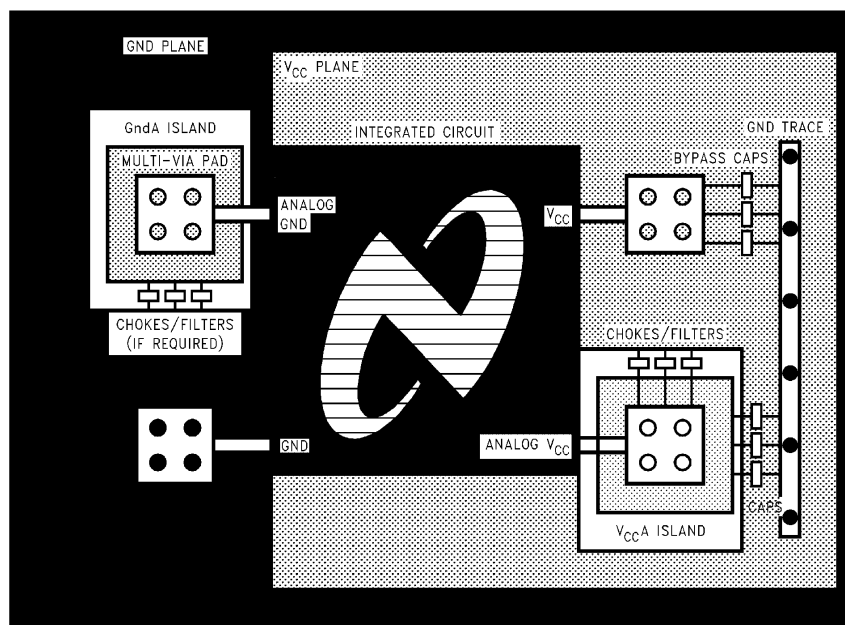


FIGURE 5. Suggested Printed Circuit Layout

TL/F/12399-6

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



National Semiconductor Corporation
1111 West Bardin Road
Arlington, TX 76017
Tel: 1(800) 272-9959
Fax: 1(800) 737-7018

National Semiconductor Europe
Fax: (+49) 0-180-530 85 86
Email: cnjwge@tevm2.nsc.com
Deutsch Tel: (+49) 0-180-530 85 85
English Tel: (+49) 0-180-532 78 32
Français Tel: (+49) 0-180-532 93 58
Italiano Tel: (+49) 0-180-534 16 80

National Semiconductor Hong Kong Ltd.
19th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
Tel: 81-043-299-2309
Fax: 81-043-299-2408