microATX EMC Design Suggestions

Version 1.0

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1. Overview

This document offers electromagnetic compatibility (EMC) design suggestions for a microATX form factor chassis. The suggestions emphasize specific system-related EMC issues (i.e., shielding, slot control, board/chassis contact, cables, peripherals) and provide information necessary to meet or exceed specified EMC requirements (U.S. and European) for radiated emissions. The design techniques that are used to suppress and contain system EMI emissions also provide immunity to radiated fields and ESD events from other sources. For board-level compliance suggestions, consult the *microATX System Design Suggestions*. EMC testing is necessary to demonstrate design performance. Figure 1 shows the radiated test criterion.

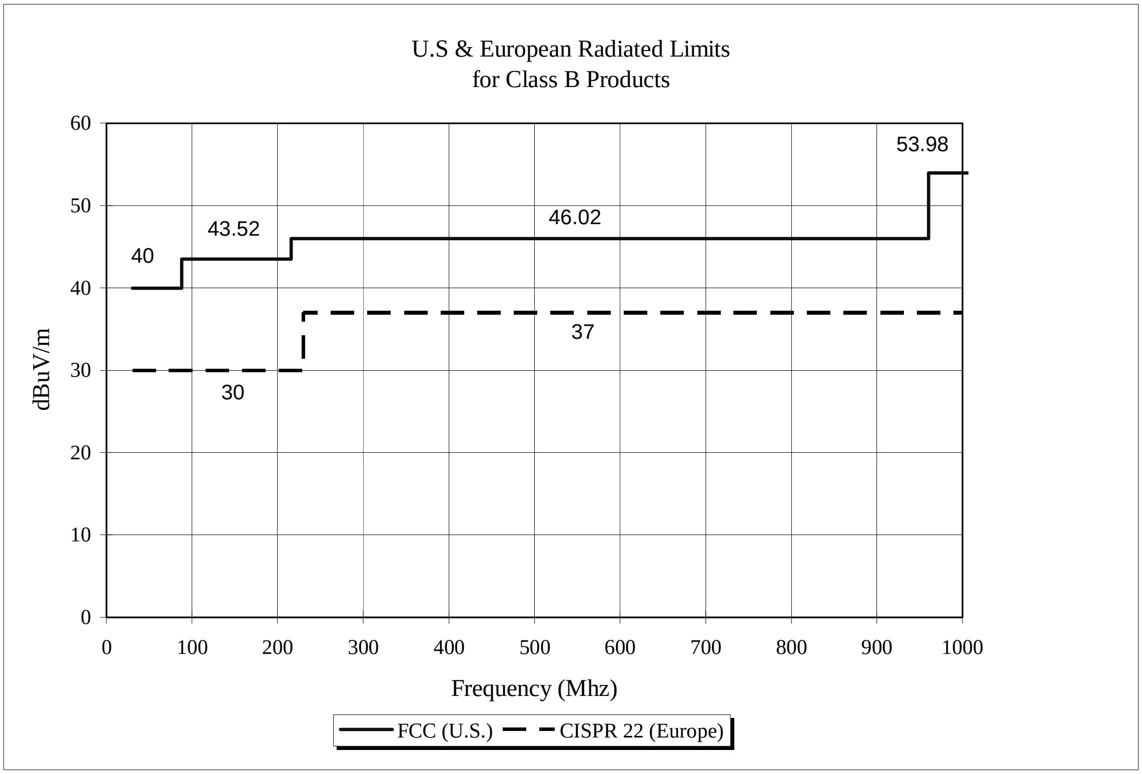


Figure 1: U.S. and European Radiated Limits for Class B Products

Note: The U.S. maximum field strength limit is based on the highest fundamental frequency (f_o) generated by the product:

If $f_o \leq$ 108 MHz, then measure to 1 GHz as shown above.

If f_o >108 MHz, then extend the 53.98 limit and measure to 2 GHz.

If $f_o \geq$ 500 MHz, then extend and test to 5 GHz.

If $f_o \geq$ 1 GHz, then extend and test to the 5th harmonic of f_o

If f_o > 8 GHz, then extend and test to 40 GHz.

In Figure 1, the lower limit is applied at the transition frequencies. The FCC antenna-to-EUT test distance is 3 meters, whereas the CISPR 22 antenna-to-EUT test distance is 10 meters.

2. Design Suggestions

Two general principles govern system EMC.

- EMI Suppression: if an electronic system does not generate EMI, then the electronic system is EMC-compliant. Suppression is generally accomplished at the board level.
- EMI Containment: if an EMI source can be completely contained, then the electronic system is EMC-compliant. Containment is generally accomplished at the system level (e.g., use of a shield).

In actual practice, using both methods optimizes the solution to EMI control. The following sections give suggestions for containment methods for systems.

2.1 DC Power Distribution

It is best to keep the wiring for the DC power as short as possible. Routing the cables next to the chassis and separating them from other cables can keep them from becoming antennas.

- Twist each internal DC power line with ground lines or shield them. This cuts the loop area and prevents the wires from behaving like antennas.
- Twist each internal DC voltage sense line with its return. Follow the manufacturer's recommendations about whether to shield these lines. Proper care of sense lines will prevent noise from coupling onto them.
- Do not daisy-chain power lines for peripheral devices. Two sets of power lines, each by itself, usually are shorter than one daisy-chained wire set. Thus, the antenna effect of the wire set is less than that of the daisy-chained wire. If it is necessary to daisy-chain power lines, then connect larger load devices closer to the power supply.
- Route DC distribution wires away from signal and AC wires to reduce cross-coupling.
- Keep internal DC power, AC power, and signal wires away from **chassis apertures**. Wires are radiators for noise in a system, and apertures leak RF energy. Radiated field strength is a function of multiple variables, including both distance to source (wire) and antenna (aperture) length. Routing wires near apertures can allow excessive emissions. See Figure 2 for a routing suggestion.

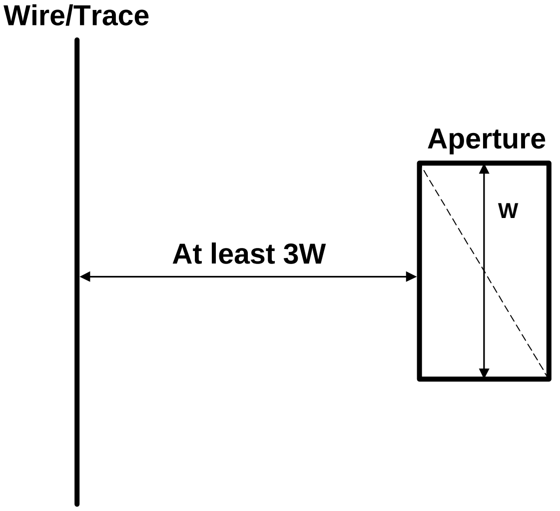


Figure 2: Aperture to Wire Spacing

For the rectangular aperture above, the maximum aperture dimension is represented by the dashed diagonal line. However, because of the antenna orientation during EMC testing, the largest dimension with respect to a vertical/horizontal axis controls the slot length. Thus, in this case, W controls maximum slot length. The testing frequency limits for current products extend to 2GHz, which corresponds to the 10th harmonic of a 200MHz clock signal. Using the $\lambda/20$ rule, set W to ¾ centimeter (see section 2.5.2, Apertures, under Chassis Considerations). At distances greater than 3W, the radiation source (wire) is in the “far field” where field strengths are significantly lower.

2.2 Internal Signal Cables

Internal signal cables are radiators of noise, which usually originates from boards. Mutual coupling occurs between parallel conductors. This coupling drops off with distance and occurs minimally in perpendicular conductors. Careful routing of cables can reduce coupling. The following list describes specific issues.

- Keep distance between a signal conductor and its return conductor to a minimum. The best number of signal conductors to return conductors ratio is 1:1. Reducing the number of return wires in a cable increases loop area and thus increases cable radiation.
- To reduce radiation, route cables closely to the chassis but away from chassis apertures.
- Provide the option for upgrading to shielded cables in case they become necessary to meet EMC requirements.
- Keep internal AC, DC, and signal wires away from chassis apertures. Wires are radiators for noise in a system, and apertures leak RF energy. Routing wires near apertures can allow excessive emissions. The recommendation is to keep all wires at least 3W away from an aperture of length W (Figure 2).
- Route internal cables away from high speed circuits to prevent cross-coupling. If a cable must be routed next to high speed logic, keep the coupling area as small as possible.
- Place sheet metal between high speed circuits and cables to help shield the cables.

2.3 External Signal Cables

External cables need to be carefully considered to meet EMC regulations. The cables must be capable of containing the noise, so the shield material and quality must be examined. The termination of the shield to connector is critical. Shield integrity must be maintained by using shield material that is not easily damaged with normal wear and tear. An alternative to shielding is to contain noise by filtering signal wires. The following subsections describe different techniques used with external cables.

NOTE

The FCC requires that the grantee either use standard external cables or ship special cables with the system. If it is possible to pass with standard off-the-shelf cables, then use them.

2.3.1 Terminating the Shield

The shields of external digital data cables **should** be terminated to chassis ground at the point of entry using one of the following methods (listed in order of preference):

1. Cable shield stops 1 inch from the back of the connector to allow signal lead connection. "Shield tape" is then used to cover the exposed area starting 1 inch from the end of the shield and continuing at a 50% overlap rate until the tape is in 360 degree electrical contact with the connector. The cable shield is to be bonded to the "shield tape" directly.
2. Shield is tied to a metal connector backshell (360 degree bond) that is bonded to chassis ground with no signal leads exposed (EMC backshell style). Ensure that the mating connector parts (e.g., backshell and frame) are not anodized or coated with any other nonconducting materials.

The above techniques are aimed at all types of signals routed externally to shielded cabinets and exposed to normal stresses of RF radiation, transients, and low-level lightning effects. Analog signals that may require added low frequency protection in the form of a cable shield terminated at one end only must still be protected against high frequency effects. To provide the needed high frequency protection, the outer shield must be terminated to the equipment chassis at the point of entry. The termination may be via a .01 to .001 microfarad capacitor that will insure high frequency termination but will block low frequency currents from flowing on the analog cable shield.

2.3.2 Connectors

- Use metal connectors that provide 360 degree contact between the mating connectors. If this is not done, the shielding effectiveness will be reduced, and a slot antenna may be created. The more contacts there are, the smaller the slot appearance is. A 360 degree connection leaves no slot at all.
- Multiconductor cable connectors can be procured with built-in bypass capacitors that are helpful in reducing cable emission. The problem frequency determines which capacitor value to use.
- Avoid using BNC connectors with a floating ground. If it is necessary to use a floating BNC connector, then bypass the shield connection to ground with one to four 0.001 µf, 1 kV capacitors.

2.3.3 Wire and Cable

- Coaxial cables improve EMI characteristics over twisted pair cables. Coaxial cable has a more uniform characteristic impedance that reduces the reflections of the signal and its harmonics. Coaxial cable has a lower capacitance than twisted pair cable and is therefore more useful at high frequencies or in high-impedance circuits.
- Use twisted pair cables to improve EMI characteristics over flat cables. With flat cables, the signal and its return may not be adjacent and would thus form a large loop antenna.
- As a last resort, pass cables one or more times through a ferrite toroid (“common mode choke”) to raise shield impedance and reduce shield currents. Ferrite beads can be used on single conductors to reduce high frequency conducted emissions.

2.3.4 Shields

- Construct shields using both foil and braid.
- Foil is typically wrapped around wires, with the nonconductive side toward the wires. This provides 100% optical coverage and an excellent shield, but one that is virtually impossible to properly terminate. The braid is used to make electrical contact with the foil and can easily be terminated.
- Consider the thickness of the foil shield. Different shield materials will require different thicknesses to provide adequate shielding.
- Use metals that are compatible with each other (see Table 1).
- Do not splice cable shielding. Different characteristic impedances are seen at the splice and can cause reflections in the cable.
- Do not use cable shields as signal returns. This causes the signal current to be present in the shield and can radiate.
- The entire cable assembly may be spiral-wrapped with a shield material (coiled spring cables, e.g., keyboard cables for PCs).

2.3.5 Unshielded Cables

Alternatives to shielding include: impedance control to minimize ringing of signals by controlling the impedance of the transmission path, filter capacitors on each signal, in-line toroids on individual wires, and a toroid around the entire cable.

No unshielded conductor should enter a shielded enclosure unless it has bypass capacitors routed to the chassis at the point of entry. Without the capacitor, the conductor can carry EMI into or out of the system.

2.4 Internal Peripherals

Peripherals that are exposed to the outside compromise system EMC design because they create a large opening in the Faraday cage. Cables that route to the peripherals can pick up system noise and carry this noise through the peripheral and out the chassis, generating EMI. Proper grounding of the peripheral can reduce this problem. A single ground, such as a wire connected to the peripheral ground tab, is not sufficient.

Peripherals may need to be enclosed behind a metal door, which can act as an EMI shield. Shielding and proper termination of cables routed to the peripheral can also help. The following list provides more details.

- Establish good contact between the peripheral frame and chassis ground to prevent the peripheral from becoming an antenna. Multiple ground points at the exposed front of the peripheral as well as the peripheral mounting points are most effective in preserving the Faraday cage (important for ESD immunity). The recommended spacing for mounting points is less than 3 inches.
- Use metal clips, EMI fingers, and screws to connect the peripheral front frame to the system chassis to cut the peripheral’s front aperture slot length. Keep slot lengths less than .75cm.
- Route the peripheral cable as short a distance as possible over high speed logic. The cable may be routed around a corner of sheet metal to isolate it from radiated noise. The cable can still pick up reflected noise, but usually after a signal has been reflected several times the signal strength has dropped significantly.
- If possible, mount the peripheral drive inside the chassis so the drive is not exposed. Another approach is to make a metal door that opens when the peripheral is accessed and closes when the peripheral is not in use. The system would only need to pass EMC certification with the door closed.
- Provide a shield between adjacent peripherals to avoid coupling between peripherals.
- Be sure that logic and chassis grounds are connected on the peripherals. Experiments have established that when logic ground floats from chassis ground, the drive can generate increased emissions. Each drive may accomplish this differently, so contact the manufacturer for information.

2.5 Chassis Considerations

The principle function of the chassis, with respect to EMC, is to contain the EMI generated within. This is accomplished by providing a tight enclosure. Metal plating, seams, and aperture sizes are important chassis features that affect EMI control. These are described in more detail below.

2.5.1 Materials Considerations

- For shielding low frequency magnetic fields (i.e., below 1 MHz), use thick, lossy materials, such as steel or mu-metal. Absorption loss is the primary shielding technique against low frequency magnetic fields. Metals with high permeability, such as steel or mu-metal, have high absorption loss. Low frequency magnetic fields are the most difficult fields to contain. Reflection loss is the primary technique against electric fields. Most thin, good conductive shields provide excellent containment of electric fields. However, apertures can significantly reduce a shield's effectiveness (see Figure 2).
- For magnetic fields of high frequency, use copper or aluminum shield material. These provide a highly conductive path between chassis parts.
- Ensure that the sheet metal thickness is adequate. Skin depth is defined as: the distance to the point inside the shield (conductor) at which the induced surface currents and fields are reduced to 37% of their surface values. The relationship for skin depth, δ, is;

$$\delta = \frac{0.06609}{\sqrt{f\mu_r\sigma_r}} \quad \text{(meters)}$$

$$\delta = \frac{2602}{\sqrt{f\mu_r\sigma_r}} \quad \text{(mils)}$$

$$\delta = \frac{2.6}{\sqrt{f\mu_r\sigma_r}} \quad \text{(inches)}$$

  where μ_r and σ_r are relative permeability and relative conductivity, respectively. Their values with respect to a given material can usually be referenced in most EMC texts ($\mu_r\sigma_r = 10$ for stainless steel 430). Frequency, f, is in units of Hertz. A sheet metal thickness of several skin depths at the lowest frequency (f) of concern should be adequate.
- Do not use metal card edge guides as grounds (causes wear and corrosion).
- Review protective coatings carefully for conductivity. Anodized materials are not conductive and are thus not suitable for seams. Review painting of parts to ensure that locations required for contact are not painted.
- Make bonding straps of solid material with a thickness of 0.020 inch rather than braided wire. To ensure the strap does not become inductive at high frequencies, keep the width greater than one fifth of the length. Solid material has a much higher conductivity than braided wire. Braid has been known to oxidize, thus degrading the conductivity. The straps must have clean metal-to-metal contacts at both ends.

- Use compatible metals in the enclosure. Otherwise, galvanic corrosion may occur. The partial galvanic series listed in Table 1 is used to determine if two metals will have a corrosion problem. When two metals are to be joined, the closer together they are on the following list, the less likely the two metals may corrode. For example, connecting zinc with copper would cause corrosion, but connecting copper to stainless steel would not.

Table 1: Galvanic Series

Group No.	Metallurgical Category	E.M.F (Volts)
1	Gold, solid and plated; Gold-Platinum alloys; wrought Platinum	+0.15
2	Rhodium plated on Silver-plated Copper	+0.05
3	Silver, solid or plated; high Silver alloys	+0
4	Nickel, solid or plated; Monel metal, high Nickel-Copper alloys, Titanium	-0.15
5	Copper, solid or plated; low brasses or bronzes; Silver solder; German Silver; high Copper-Nickel alloys; Nickel-Chromium alloys; austenitic stainless steels	-0.20
6	Commercial yellow brasses and bronzes	-0.25
7	High brasses and bronzes; Naval brass; Muntz metal	-0.30
8	18% Chromium type corrosion-resistant steels	-0.35
9	Chromium, plated; Tin, plated; 12% Chromium type corrosion-resistant steels	-0.45
10	Tin-plate; Terne plate; Tin-Lead solders	-0.50
11	Lead, solid or plated; high Lead alloys	-0.55
12	Aluminum, wrought alloys of the duralumin type	-0.60
13	Iron, wrought, gray or malleable; plain carbon and low alloy steels; armco iron	-0.70
14	Aluminum, wrought alloys other than duralumin type; Aluminum cast alloys of the silicon type	-0.75
15	Aluminum, cast alloys other than silicon type; Cadmium, plated and chromated	-0.80
16	Hot-dip-Zinc plate; galvanized steel	-1.05
17	Zinc, wrought; Zinc-base die-casting	-1.10
18	Magnesium and Magnesium-base alloys cast or wrought	-1.60

Note: For unlisted metals in intimate contact, contact an EMC engineer for a determination of compatibility. In general, metals within 0.35V of each other on this chart should be considered acceptable.

2.5.2 Apertures

Keep maximum linear dimensions of ventilation apertures, I/O ports, and open areas along chassis seams less than 1/20th of a wavelength (λ) of the highest harmonic frequency (f) of concern (1/20th rule, see also Figure 2). Absorption and shield thickness may contain low frequency magnetic fields, but high frequency electric field radiation out of slots becomes the next concern. Apertures (or slots) can be viewed as half-wave dipole antennas and are thus able to radiate maximum energy at dimensions of 1/2 a wavelength. In fact, slots longer than 1/100th of a wavelength can cause considerable leakage. Therefore, it is necessary to keep slot lengths as short as possible to minimize leakage. Currently, the FCC has requirements up to 2 GHz, which, as derived below, correspond to a recommended maximum aperture size (vertical or horizontal) of about .75 centimeters; for example:

$$C = f\lambda$$

or

$$\lambda = \frac{C}{f}$$

where C is the speed of light (3.00×10^8 m/s).

From this we define the 1/20th rule:

$$\frac{\lambda}{20} = \frac{1500}{f}$$

$$L = \frac{\lambda}{20}$$

where λ and L are in centimeters (cm) and f is in Megahertz (MHz).

The shielding effectiveness, S , in decibels (dB), for a single slot of length, L , is defined as:

$$S = 20\log\left[\frac{150}{f \times L}\right] \quad \text{(dB)}$$

or in terms of L ;

$$L = 10^{\log\left(\frac{150}{f}\right) - \frac{S}{20}} = \frac{150}{f \times 10^{S/20}}$$

for units of f (MHz) and L (meters)

and L $\leq$ ½ wavelength.

For multiple apertures of equal size, on one side of a chassis, and placed 1/2 wavelength or less apart, the shielding effectiveness for the side decreases as the square root of the number of apertures (*n*):

$$S = -20\log\sqrt{n} = -10\log n \quad \text{(dB)}$$

Example: Test results show a product requires 10dB of shielding effectiveness on one side at 2 GHz. If there are 30 equal length slots, how long should each slot be?

Solution (using above relations):

- 30 slots will reduce the shielding effectiveness (that would have been derived from one slot) by 15dB.
- To compensate, each slot must provide 25dB (10dB + 15dB = 25dB) of shielding effectiveness.
- To provide 25dB of shielding effectiveness at 2 GHz, each slot should be L = 0.42cm.

Multiple apertures of the same size reduce shielding effectiveness; however, multiple apertures produce less leakage than a single large aperture of the same total area.

If more shielding effectiveness is required, the concept of "waveguide below cutoff" may be implemented (see Figure 3). This concept states that, for incident frequencies, f, much less than the guide cutoff frequency, f_c, fields propagating in the guide are attenuated in direct proportion to the distance the fields travel (d) through the guide. The cutoff frequency is defined as:

$$f_c = \frac{1.758 \times 10^4}{L}, \quad \text{for a \underline{round} waveguide}$$

$$f_c = \frac{1.500 \times 10^4}{L}, \quad \text{for a \underline{rectangular} waveguide}$$

for L in centimeters and f_c in MHz

As seen from these relationships, slot length L controls the waveguide cutoff frequency. Using L from the 1/20th rule, the incident frequency f is much less than f_c. In this case, the shielding effectiveness afforded by one guide is given as:

$$S = 32\frac{d}{L} \quad \text{(dB), for a \underline{round} waveguide}$$

$$S = 27.3\frac{d}{L} \quad \text{(dB), for a \underline{rectangular} waveguide}$$

This relationship shows that for a given slot length, L (maximum linear dimension), the guide propagation dimension, d, can be chosen to provide the required degree of shielding effectiveness. A waveguide can therefore be used to obtain more shielding effectiveness from a single slot or to compensate for reduction in shielding effectiveness from multiple slots. By using the appropriate waveguide solution, proper system ventilation can be maintained without EMC degradation. See Figure 3.

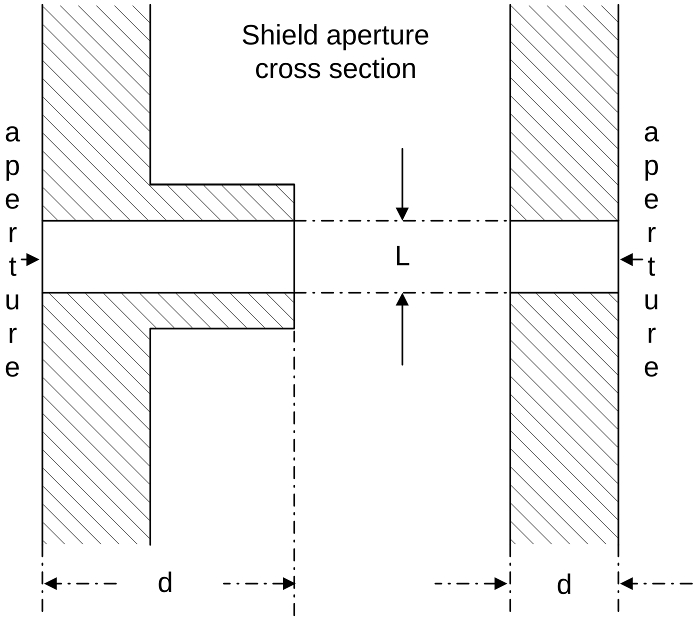


Figure 3: Waveguide Below Cutoff

2.5.3 Time to Frequency Domain

Figure 4 relates a time domain trapezoidal waveform to the frequency domain. The waveform shown is a typical trapezoid with the given parameters. The bottom plot shows the "envelope" that contains the amplitudes of the trapezoid's harmonics across the frequency spectrum (spectral content). Starting at $f_1 = 1/\pi t_w$, the maximum harmonic voltage drops at a rate of -20 dB/decade. At $f_2 = 1/\pi t_r$, the maximum harmonic voltage drops at a rate of -40 dB/decade.

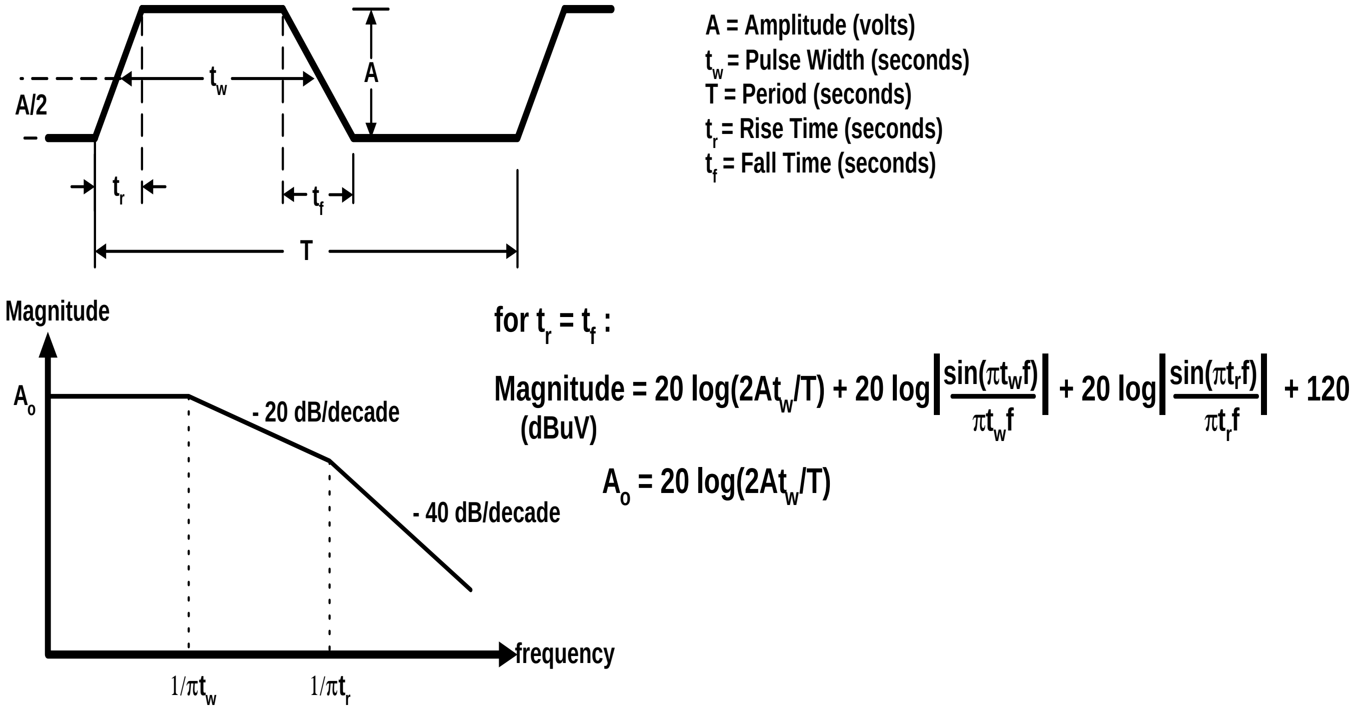
Example: To calculate f_2, consider a 33 MHz signal with a 1 ns rise-time:

$$f_2 = \frac{1}{\pi * (1ns)} = 318 \text{ MHz}$$

Frequencies significantly higher than f_2 (beyond the 10th harmonic) usually cause few problems, because the energy content drops off so rapidly.

NOTE

The above analysis assumes a perfect trapezoidal signal, and thus the effects of ringing from imperfectly terminated transmission lines are not included. These effects can increase emission problems.



for $t_r = t_f$:

$$\text{Magnitude (dBuV)} = 20\log(2At_w/T) + 20\log\left|\frac{\sin(\pi t_w f)}{\pi t_w f}\right| + 20\log\left|\frac{\sin(\pi t_r f)}{\pi t_r f}\right| + 120$$

$$A_o = 20\log(2At_w/T)$$

Figure 4: Time to Frequency Domain Parameters

2.5.4 Keep Apertures Clear

Keep crystals and oscillators as far away from apertures as possible.

2.5.5 Provide Direct Metal-to-metal Contact

Connect shielding materials through direct metal-to-metal contact—do not use screws to form the conduction path. Overlap the connections by at least 1/2 inch. The fastening method should provide sufficient pressure to hold the surfaces in contact in the presence of deforming stresses, shocks, and vibrations associated with the equipment and its environment. If screws are used to hold surfaces together, the recommended spacing is 3 inches.

2.5.6 Provide Solid Ground at I/O Connector

A solid ground is essential at the I/O connector to chassis and ground plane.

2.5.7 Provide Better Shielding with Numerous Small Holes

A large number of small holes give better shielding than a single large hole of the same area. Either large holes or small holes placed too close together can become significant slot antennas. Space small holes apart by a distance equal to the diameter of the hole ($\lambda / 20$). Reduce emissions from large holes by placing screens over large holes or forming a “waveguide below cutoff.”

2.5.8 Bond Metal Components Together

Bond together all metal components or assemblies within a shielded enclosure. When any conductive object is not grounded, it can become an antenna.

2.5.9 Minimize DC Resistance Between Shielding Sections

Ensure the DC resistance between sections of shielding (or bonds) is less than 2.5 mΩ (MIL-B-5087B). Make measurements with a light pressure applied to nonpointed probes. A low DC resistance *does not* guarantee a low impedance at high frequencies. Conversely, a high DC resistance *will* guarantee a high impedance at high frequencies.

To acquire a more accurate AC impedance measurement, use a Radio Frequency Impedance Bridge. When mounting the motherboard to the chassis, it is not feasible to position conductive ground points apart by $\lambda/20$ for higher frequencies. It is suggested that ground contacts be made via the ground pads at the mounting holes that are defined in the *microATX Motherboard Interface Specification*.. Using the I/O shield as a “single point ground” may cause the motherboard and chassis ground to be at different potentials and thus generate EMI. In this case, however, it may be possible to contain noise by other means, including a well designed system EMI shield.

2.5.10 Connect Exterior Metal Parts to Chassis

Connect exterior metal parts to chassis to prevent re-radiating EMI. Exterior metal parts that are not properly bonded to the chassis can become antennas, especially when placed next to apertures. This is especially true when a part is placed next to vents.

2.5.11 Estimate EMI Sources to Determine Amount of Shielding

If possible, estimate the EMI sources inside the box and determine how much shielding is needed. Try to anticipate which frequencies will be used by future upgrades.

3. Design Checklist

This section provides an informal checklist of suggestions about electromagnetic compatibility (EMC) for a microATX form factor chassis. The checklist is meant for reference only and is not intended to be comprehensive.

NOTE

It is strongly recommended that the designer review the *microATX Motherboard Interface Specification* in sufficient detail to be confident that the design complies with the specification.

— Has the worst case analysis been done to determine frequencies to shield, allowed distances, and maximum allowed aperture sizes for the system?

DC Power Distribution

— Have internal DC power lines been twisted with ground lines or shielded?

— Have internal DC voltage sense lines been twisted?

— Have internal DC distribution wires been routed away from signal and AC wires?

— Have internal DC wires been routed away from apertures?

Cables

— Have internal signal cables been routed away from apertures?

— Have cable shields been grounded at both ends?

— Do cable shields have a 360 degree soldered connection to the backshell?

— Do metal connectors provide 360 degree connection to the mating connector?

— Do shields consist of both foil and braid?

— If any unshielded conductors enter a shielded enclosure, do they have bypass capacitors at the point of entry?

— Do all shielded cables entering an enclosure have the shield connected or bypassed to the enclosure shield?

— Are shielding materials thick enough?

— Has pigtail termination been avoided? If used, is the length of a ground conductor (pig-tail) kept shorter than 1 inch?

— Are foil shields used in combination with braid?

— Are floating BNC connectors avoided? If used, is the shield connection bypassed to ground with 0.001 µf 1 kV capacitors?

Internal Peripherals

- Is good contact established between the peripheral chassis and the chassis ground of the system enclosure?
- Is a shield provided between peripherals to avoid coupling?
- Are logic and chassis grounds connected on the peripherals?

Chassis

- For shielding of high frequency magnetic fields, is copper or aluminum shield material used?
- Are ventilation apertures, I/O ports, and open areas along chassis seams kept to dimensions less than a 1/20th wavelength of the highest frequency of concern?
- Are crystals and oscillators kept as far away as possible from apertures?
- Are shielding materials connected through direct metal-to metal contact, not just through screws?
- Do connections between shielding materials overlap by at least 1/2 inch?

Bonding

- Do bonding straps have a length not greater than five times the width and a minimum thickness of 0.020 inch?
- Do bonding straps have clean metal-to-metal contact at both ends?
- Has contact between shielding surfaces been checked for impairment because of the application of paint?
- Are all metal components or assemblies within a shielded enclosure bonded together?
- Is shielding material thick enough?
- Is the resistance between sections of shielding (bonds) 2.5 milliohms or less?
- Has the use of metal card edge guides as grounds been avoided?
- Does the fastening method provide sufficient pressure to hold the surfaces in contact in the presence of deforming stresses, shocks, and vibrations associated with the equipment and its environment?
- Are compatible metals used in the enclosure to avoid galvanic corrosion?
- Are exterior metal parts properly connected to the chassis to prevent radiating EMI?

4. Definitions

Aperture

In an enclosure that contains EMI (using the Faraday cage concept), an aperture is defined as any opening to the outside. The maximum allowable size of the opening is largely a function of the EMI frequency to be contained. Other aspects include how close any internal radiator is to the aperture, and how thick the shield material is.

Bond (noun)

A bond is any fixed union existing between two objects that results in electrical conductivity between the two objects. Such union occurs either from physical contact between conducting surfaces of the objects or from the addition of a firm electrical connection between them. (MIL-B-5087B)

Braided Wire

Tightly interwoven wire mesh used as grounding or shielding material in electronic circuits and cables.

Common Mode Noise

Refers to an electrical current flowing through multiple conductor paths. For example, a printer interface cable may have a common unwanted signal flowing in the same direction in every conductor within the cable. Current may flow from the system to the printer or the printer to the system and may be present not only on the signal wire but also on the cable shield. Because electrons must find a way back to the original source, these common mode currents will find a path back to the system or printer. This return path, which may be through earth ground or other cables, creates a large loop antenna and radiates the common mode noise.

Conducted Emission

Electromagnetic emissions propagated along a power or signal conductor. (MIL-STD-463A)

Degradation

Any out-of-tolerance condition that occurs during EMC testing. (MIL-STD-463A)

Differential Mode Noise

Refers to the noise that may be generated between a signal and its return line. For example, a signal that leaves a board must have a return path to the board. If the return line is not located nearby, then the large loop area will allow the generation of a radiated field.

EMC

Electromagnetic Compatibility (EMC). The condition that prevails when electronic equipment is collectively performing its individual designed functions in a common electromagnetic environment without causing or suffering unacceptable degradation because of electromagnetic interference to, or from, other equipment in the same environment. (MIL-STD-463A)

EMI

Electromagnetic Interference (EMI). Any electromagnetic energy that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic equipment. (MIL-STD-463A)

Emission

Electromagnetic energy propagated from a source by radiation or conduction. (MIL-STD-463A)

EUT

Equipment Under Test.

Faraday Cage

A type of EMI shield that interposes a complete conductive or absorptive blockage between a noise and a receptor. The term refers not only to physical shields but also to the use of bypass capacitors on the signals that enter and/or exit the shield. To maintain a perfect Faraday cage over a wide range of frequencies, no apertures may exist in the shield. However, penetrating the shield is usually the case because of cable I/O and ventilation requirements.

Floating Ground

In some cases it may not be possible to terminate a cable shield or a backplane signal ground directly to chassis ground. An alternative approach is to place capacitors between the cable shield or backplane signal ground and chassis ground. The capacitors will appear as a "short" at high frequencies and thus will be effective in making the cable shield or backplane signal ground appear as though each is connected to chassis ground at high frequencies.

Harmonics

From Fourier’s concepts, we can treat a nonsinusoidal, periodic signal as a signal composed of multiple sine waves of different frequencies. For example, a 33 MHz, trapezoidal clock signal will have sinusoidal components at frequencies above 33 MHz. In general, at each multiple of the fundamental frequency, for example, 66, 99, 132 MHz and so on, energy can be found because of the 33 MHz fundamental frequency. These other frequency components can be seen using a spectrum analyzer. So, when considering the highest frequency to design the board and system to, note that although the 33 MHz signal may not cause problems, one of its harmonics may. The 10th harmonic of a 33 MHz fundamental frequency is 330 MHz. As a rule-of-thumb, significant energy exists for harmonics up to 10 times their fundamental frequency.

High Edge Rate

For this document, "high edge rate" is meant to indicate a signal with a transition time of faster than 20 ns. Higher edge rates generate more EMI (signal rise time is inversely proportional to spectral bandwidth). Slower edge rates can still generate EMI. Periodic signals with ringing (because of impedance mismatches) can generate EMI even if the signal’s edge rate and frequency are low. Signals that have edge rates less than 5 ns should be given special attention.

High Frequency

For this document, "high frequency" is defined as all signals with a frequency of 10 Megahertz (MHz) or greater.

High Speed Signals

For this document, "high speed signals" are defined as signals that, because of their wavelength and the length of the path in the circuit, must be treated as traveling along a transmission line.

Loop Area

The area between a signal and its return path is referred to as the loop area.

Radiated Emission

Desired or undesired electromagnetic energy that is propagated through space. If it is undesired, such an emission is called "radiated interference." (MIL-STD-463A)

RFI

Radio Frequency Interference is an older term for Electromagnetic Interference (EMI).

Shield

A barrier that encloses or shadows a device for the purpose of preventing or reducing the transmission of electrical energy (see Faraday cage). The barrier can be conductive, dielectric, or have a nonmetallic absorptive core. (MIL-STD-463A)

Shielding Effectiveness

Ratio of the magnitude of the electric (magnetic) field that is incident (E_i) on the barrier, to the magnitude of the electric (magnetic) field that is transmitted (E_t) through the barrier, i.e.:

$$S = 20\log\left[\frac{E_i}{E_t}\right] \text{ (decibels)}$$

Slot Antenna

A slot antenna is formed by any opening or aperture in a chassis that will allow radiated noise to exit the enclosure. Optimum slot antenna efficiency is achieved when the slot length is one half the wave length of the frequency of interest. Because we do not want an optimum slot antenna, a good maximum aperture is 1/20 or less of the shortest wavelength of interest.

Transmission Lines

High speed signal conductors of such uniformity that inductance, capacitance, and resistance can be expressed in per unit length quantities; e.g., 10 mH/inch for a typical trace inductance.

For slow signals the transmission line characteristics can be ignored. The transmission line concepts become important with signals that have a rise-time that is less than the time required for the signal to travel from the driver to the end of the line and back. Proper signal termination on transmission lines can reduce the high frequency reflections that contribute to EMI.

Transmission line effects must be considered for any circuit that becomes electrically large, i.e., one that has dimensions larger than about 1/10 of a wavelength at the frequency of interest.