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# Noise Suppression by EMIFIL® Digital Equipment

## Application Manual

**muRata** *Innovator in Electronics*

**Murata Manufacturing Co., Ltd.**

**Cat.No.C33E**

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## *Introduction*

Because the process of EMI noise emission, conduction and radiation from electronic circuits is complicated, it is very difficult for us to suppress such EMI noise. To improve noise suppression efficiency, we must thoroughly examine the places and methods for taking noise suppressing measures.

In the first half of this manual, by referring to experimental data, we will explain how electronic circuits emit EMI noise and how EMI noise is conducted through and radiated from circuits. Also, we will explain the techniques for suppressing EMI noise. The second half of this manual describes the precautions for using EMI suppression filters for noise suppression, and presents examples of EMI suppression filter applications in typical electronic circuits.

We invite you to refer to this manual when considering noise suppressing measures.

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# 1  Noise Sources in Digital Equipment

The electronic circuits that may raise EMI noise problems use many ICs, which makes the process of EMI noise emission very complicated. To explain the EMI noise phenomena simply, this chapter describes how electronic circuits, for example, experimental circuits with only two or three ICs, emit EMI noise.

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## Noise Sources in Digital Equipment  1

## 1. Digital Signals and Harmonic Components
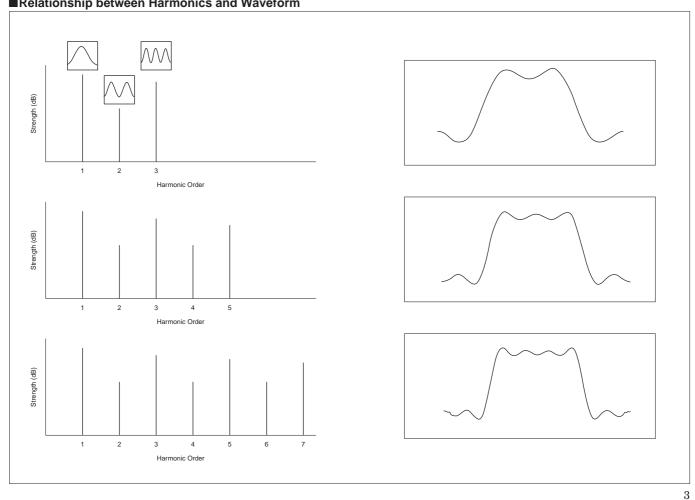
As a cause of EMI noise emission from an electronic circuit, a digital signal used in the electronic circuit is considered.

A digital signal shows a rectangular voltage waveform, which is formed by overlaying many sine waves. The frequencies of these sine waves are integer times the repetition frequency of the digital signal. A sine wave with a frequency equal to the repetition frequency is called a fundamental wave, and those with a frequency n times the repetition frequency are called $n^{th}$-order harmonics. The charts above show the signal wave calculation results, indicating that the resulting waveform gradually becomes close to a rectangular wave as a fundamental wave is combined with higher-order harmonics.

From these charts, you can see that a signal with a sharper rising/falling edge is comprised of higher-order harmonics, i.e. higher frequency components.

A digital signal with a 50% duty ratio is formed by harmonics based only on odd numbers. However, if the duty ratio is not 50%, the signal also includes harmonics based on even numbers.

■Digital Signals Higher Harmonics Analysis Model



$T$ : Cycle Time
$\frac{t}{T}$ =d : Duty Ratio

$$f(x)=d(1+2A_1\cos w_0 t+2A_2\cos 2w_0 t+...)$$
$$w_0=2\pi/T, Ak=\frac{\sin k\pi d}{k\pi d} \ (k=1,2,...)$$

■Relationship between Harmonics and Waveform

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# 1 Noise Sources in Digital Equipment

## Example of Digital's Spectrum Measurement
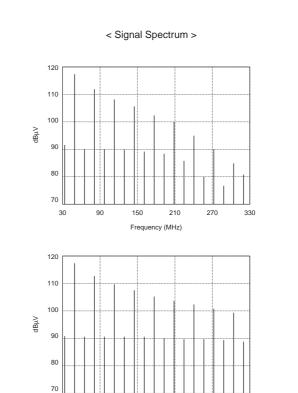
The charts above show the harmonics, measured by a spectrum analyzer, included in an actual digital signal. The digital signal is comprised of several ten[th] or higher-order harmonics. You can see that the frequency of this signal reaches several hundred megahertz.

The harmonics included in the digital signal are considered a principal cause of EMI noise emission from the electronic circuit. Because of the high frequencies, harmonics radiate easily. If a harmonic frequency is close to the frequency of a radio or TV broadcast signal, the harmonics will be superimposed on the radio wave, causing receiving interference.

■Test Circuit



< Signal Waveform >

Found Value



H : 10ns/diV
V : 1V/diV

(Reference) Calculated Waveform



H : 10ns/diV
V : 1V/diV

< Signal Spectrum >





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# Noise Sources in Digital Equipment  **1**

## Noise in IC Power Supply Line

Power supply noise is considered as another cause of EMI noise emission from electronic circuits. Digital IC's use DC power supplies, and the DC current on the digital IC's power supply terminal will be interrupted according to the IC operation. Such a sporadic change in current causes EMI noise.

The charts above show the voltages, measured with an oscilloscope and a spectrum analyzer, on a power supply terminal of an IC that will operate at 5MHz. According to the IC operation timing, the power supply terminal outputs an oscillation waveform, and the spectrum analysis data on this oscillation waveform proves that harmonics are included in the waveform. These harmonic components cause EMI noise.

■**Test Circuit**



< Power Supply Waveform >



-250.000 ns        0.00000 s        250.000 ns

| Cn.1     = 200.0 mVolts/diV | Offset = 5.200 Volts |
| F100000 = 50.0 ns/diV | Delay  = 0.00000 s |

200mV · 50ns/diV

< Noise Spectrum >



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# 1 Noise Sources in Digital Equipment

## 2. Radiated Noise from Digital Circuit Boards

### Noise Generated by IC

On the previous pages, we explained that noise emission occurs according to the digital IC operation. Now, we will explain how the noise is conducted through and radiated from digital circuits by referring to some experimental circuits.

As the simplest example of a digital circuit, we prepared an oscillation circuit on a PWB, and measured the noise radiation from this PWB.
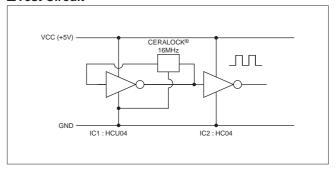
This PWB is single-sided. Part of the front side is equipped with the circuit, and the residual part of the front side is entirely grounded. On the above PWB, IC1 oscillates at 16MHz, and the signal output terminal of IC2 that receives the oscillation signal is open.

Both ICs' power supply terminals are equipped with noise suppression components, so that the noise radiation from the power supply terminal can be thoroughly suppressed.

The chart above shows the noise radiated from this PWB measured at a distance of 3m. You can see that the noise level is sufficiently low relative to the CISPRpub.22 limit value.
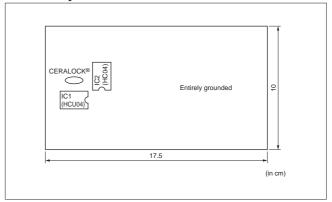
To radiate noise, both noise source and noise radiation antenna are required. Because the above PWB has no noise antenna, although its IC serves as a noise source, we consider that the noise radiated from this PWB is low.
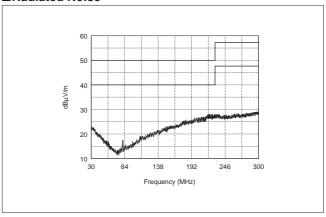
With some of the recently used large ICs, their package itself may serve as a noise antenna. In this case, the noise radiation from the IC package cannot be ignored.

■**Test Circuit**



■**Board Layout**



■**Radiated Noise**

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## Noise Sources in Digital Equipment **1**

### Radiated Noise from Patterns
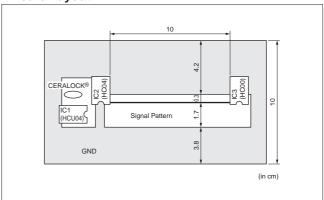
Now we will show an experimental circuit with a noise source connected to a signal pattern that serves as a noise antenna. As shown in the diagram above, the IC2 output terminal, which is open in the previous experiment, is connected to an approx. 10cm signal pattern, and the signal pattern is terminated with IC3. The noise radiation measurement from this PWB is shown in the chart above. From noting the harmonics with the IC oscillation frequency, i.e. 16MHz on this chart, you can see that the noise levels at some frequencies exceed the CISPRpub.22 limit value. This phenomenon is probably because a noise antenna is formed on the PWB when the IC2 output terminal is connected to the signal pattern.
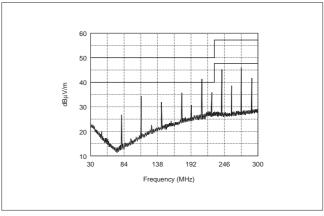
This noise antenna is made by the following signal current flow: IC2 –> signal pattern –> IC3 –> GND –> IC2. As shown in this example, the noise conducted in the same level and in the reverse direction due to the current flow between the signal pattern and GND pattern is called "normal mode noise" (differential mode noise). In this case, the noise and signal will flow in the same conduction mode.

■**Test Circuit**



■**Board Layout**



(in cm)

■**Radiated Noise**

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# 1 Noise Sources in Digital Equipment

## Effect of EMI Suppression Filter
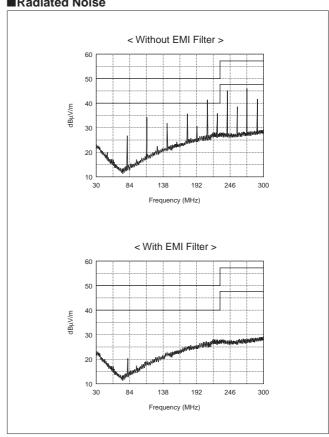
This chart shows the result of the experiment for suppressing the noise radiated through a signal pattern that serves as a noise antenna (normal mode noise). Inserting an EMI suppression filter between the IC2 output terminal and the signal pattern can remarkably suppress the noise level. The EMI suppression filter used in this experiment is a combination of the chip EMIFIL® for the signal line and a 30Ω resistor, so that distortion of the digital signal waveform can be suppressed.

■**Test Circuit**



■**Board Layout**



(in cm)

■**Radiated Noise**



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## Noise Sources in Digital Equipment   1

## 3. Radiated Noise from Cables

### Radiated Noise from Cable (1)

We will now show an example where IC2, or a noise source, is connected to a cable instead of the signal pattern.
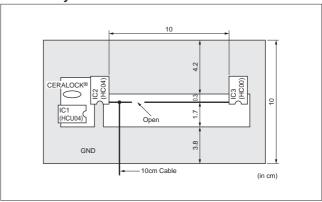
As shown above, the IC2 output terminal is disconnected from the signal pattern, and connected to a 10cm cable that has the same length as the signal pattern. The noise radiated from this circuit is shown in the charts above. In comparison with the previous case, where the signal pattern is connected, the noise level in this experiment is increased by approx. 10dB at the maximum. You can see that the cable serves as a more efficient noise antenna than the signal pattern.
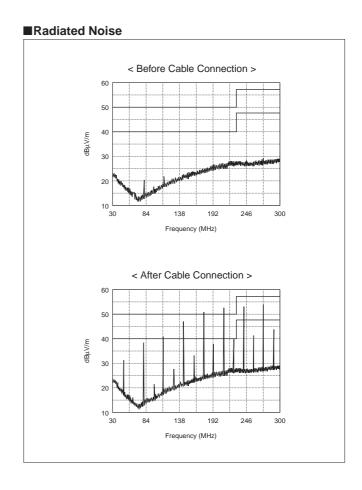
When a signal is connected with a cable as shown above, you must be aware of the strong noise radiation from the cable.

■**Test Circuit**



■**Board Layout**



■**Radiated Noise**

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## 1 Noise Sources in Digital Equipment

### Example of Suppressing Radiated Noise from Cable (1)
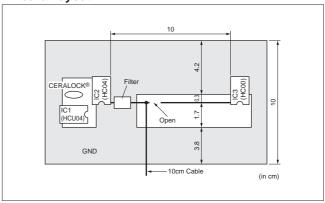
These charts show the results of the experiment for suppressing noise radiation through the cable that serves as an antenna. As with the case using the signal pattern, inserting an EMI suppression filter between the IC2 output terminal and the cable can remarkably reduce the noise level.
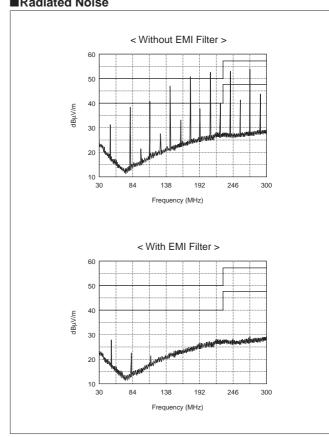
In the case where a noise source is directly connected with a noise radiation antenna as shown, inserting an EMI suppression filter between the noise source and the antenna results in a large noise suppressing effect.

■Test Circuit



■Board Layout



■Radiated Noise

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# Noise Sources in Digital Equipment  **1**

## Radiated Noise from Cable (2)
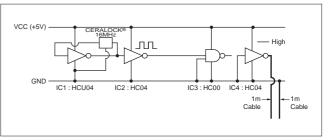
The next example shows a case where a cable mounted to a PWB serves as an antenna through which noise is radiated. As shown above, a signal pattern is connected between IC2 and IC3 on a PWB, IC4 is mounted at the end of the PWB, and a 1m cable is connected to the IC4 output terminal and GND. This cable is assumed to be an interface cable. In this example, we suppose that IC4 will not operate, assuming that the interface circuit is not activated. Therefore, no signal current is flowing through the cable.

The charts show the radiation noise levels measured before and after the cable connection. You can see that the noise level increased remarkably after the cable connection. In particular, it increased by 30dB at a frequency of around 80MHz.
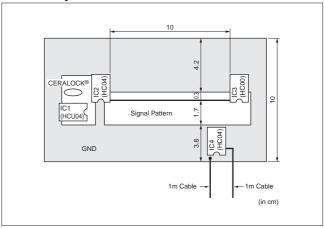
This phenomenon is probably because the noise emitted from IC2 is conducted into IC4 via the power supply line or GND line, and radiated from IC4 through the cable that serves as a noise antenna. Also, we can consider that the cause of the remarkable increase in noise level at around 80MHz is that the cable serves as an antenna with 1/4 of the wavelength at this frequency.
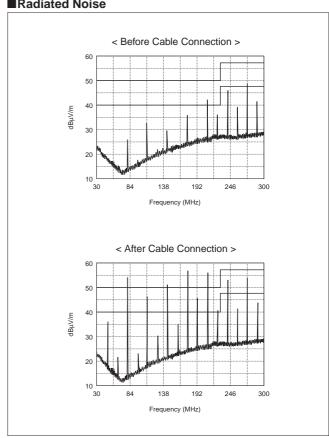
In actual electronic equipment connecting an interface cable, we frequently see a similar phenomenon when the interface circuit receives the noise emitted from the internal circuit, and the interface cable serves as an antenna through which the noise is radiated.

### ■Test Circuit



### ■Board Layout



### ■Radiated Noise

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# 1 Noise Sources in Digital Equipment

## Radiated Noise from Cable (3)

This experiment is intended to examine whether the noise conducted through the cable in the previous experiment is flowing on the signal line or GND line of the cable. In this experiment, we measured the radiation noise level by connecting either the signal line or GND line. The noise levels, with only the signal line or the GND line, are almost equal to the noise level observed with both these lines. The charts show the noise levels with only the GND line after the signal line is disconnected.
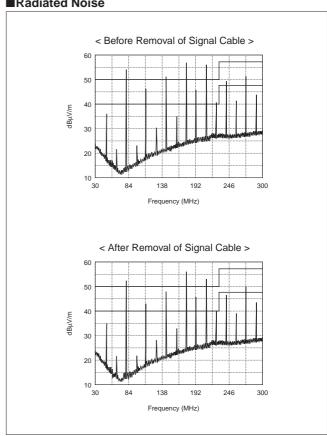
From the results of this experiment, we can see that the same level of noise is conducted through the signal line and GND line, and the signal line and GND line function like a single noise antenna. As shown above, the noise conducted in the same level and in the same direction due to the current flowing through all lines is called "common mode noise."

### ■Test Circuit



### ■Board Layout



(in cm)

### ■Radiated Noise



< Before Removal of Signal Cable >

< After Removal of Signal Cable >

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# Noise Sources in Digital Equipment  **1**

## Example of Suppressing Radiated Noise from Cable (2)

This diagram shows an example of the noise suppression circuit that uses the cable described in the previous experiment as an antenna for radiating common mode noise. In this experiment, a GND plane is used to improve the GND condition so that the common mode noise conducted through the GND line can be suppressed. Furthermore, an EMI suppression filter is connected to the IC2 output terminal so that the noise radiated from the signal pattern can be suppressed. Through these noise suppressing measures, the radiation noise level can be reduced markedly.

The GND plane is made of a metal plate with almost the same size as the PWB. The metal plate is placed under the PWB, and the GND terminals on the PWB are connected with several parts of the metal plate. Using the GND plane is effective in suppressing the common mode noise conducted through the GND line.

To suppress common mode noise, you can use a common mode choke coil, in addition to the GND improvement method.

### ■Test Circuit



### ■Board Layout



### ■Radiated Noise



< Before Test >



< After Ground Plane is added >



< After EMI Suppression Filter is added >

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# 1 Noise Sources in Digital Equipment

## Radiated Noise from Cable (4)

Now consider the case where the interface circuit is being activated.
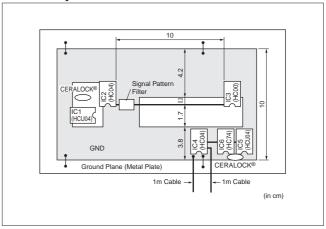
On the experimental PWB with noise suppression measures taken as shown above, a 750kHz oscillation circuit is connected to IC4 to generate a 750kHz digital signal from its output terminal. The charts show the noise radiation from this PWB. When the cable receives the 750kHz signal input, the harmonics of this signal are radiated through the cable.
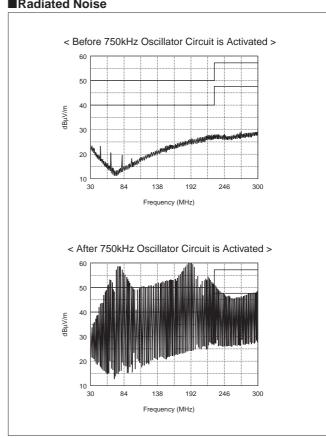
As shown, a signal flowing through an interface cable may cause radiation noise.

■**Test Circuit**



■**Board Layout**



■**Radiated Noise**



< Before 750kHz Oscillator Circuit is Activated >

< After 750kHz Oscillator Circuit is Activated >

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## Noise Sources in Digital Equipment  **1**

## Example of Suppressing Radiated Noise from Cable (3)

The diagram shows an example of the noise suppression circuit for suppressing radiation noise due to the signal flowing through a cable. In this experiment, an EMI suppression filter is connected between the cable and IC4 that serves as a new noise source. First, a combination of chip EMIFIL® and chip ferrite beads inductor is connected to the signal line. As a result, most of the radiation noise can be eliminated. Then, another chip ferrite beads inductor is connected to the GND line, resulting in a further noise suppressing effect.
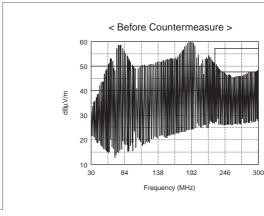
As shown, taking noise suppressing measures for both the signal line and GND line can improve the noise suppressing effect.

■**Test Circuit**

■**Board Layout**

■**Radiated Noise**

< Before Countermeasure >

< With EMI Filter on Signal Line >

< With EMI Filter on Ground Line >

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## 1   **Noise Sources in Digital Equipment**

**1**

## 4. Causes of Common Mode Noise

Now we will discuss the causes of the common mode noise observed in the previous experimental circuit. In this experimental circuit, a 16MHz digital signal is generated from IC2, and transmitted to IC3. If the GND functions ideally in this circuit, there should be no voltage on the GND terminal, and accordingly no common mode noise. However, since the GND pattern on this experimental PWB is relatively small, the GND pattern has inductance, causing voltage on the GND terminal due to the return current of the signal. It can be considered as a cause of the common mode noise. In addition to this, the power supply current flowing through the IC generates a voltage on the GND terminal, causing common mode noise.
To suppress the common mode noise, it is effective to reduce the GND impedance through GND improvement, or to connect EMI suppression filters to the signal line and power supply line to reduce the return current.
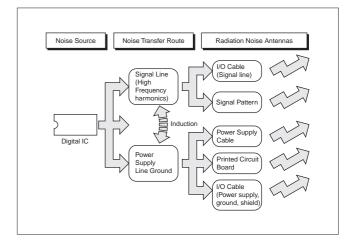


## 5. Summary of EMI Noise Sources

This diagram summarizes the descriptions on the previous pages. A digital IC serves as a noise source, and noise is conducted through a signal line, power supply line and GND line. When the noise flowing through these lines is radiated directly from the PWB or radiated via an I/O cable or power supply cable that serves as an antenna, noise interference occurs. The noise suppression using EMI suppression filters is intended to suppress noise radiation by eliminating the noise flowing through these transmission lines.

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# **2** **Suppressing EMI Noise Emission**

**2**

This chapter provides techniques for using EMI suppression filters to suppress noise radiation from a PWB.

For your reference on PWB design, we will present the noise measurement data taken by changing the component or pattern layout on a PWB, and by improving the GND condition. Furthermore, for your reference on PWB shielding, we will present the measurement data on variations in noise suppressing effect depending on the opening dimension of the shielding.

## 1. Approaches to Suppressing Emission of EMI Noise
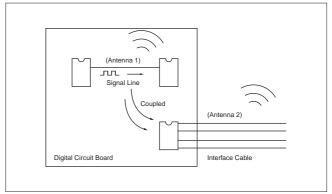
### EMI Noise Emission Suppression Model

These diagrams show the noise suppression models of a PWB using EMI suppression filters. The noise emitted from a digital IC is radiated through a signal line that serves as an antenna, or conducted into an interface circuit and then radiated from the interface cable that also serves as an antenna.
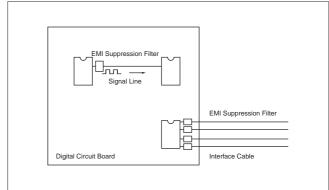
To suppress such noise, it is effective to connect an EMI suppression filter to the signal line from which the noise will be emitted first.

If the relevant circuit cannot be identified, or an EMI suppression filter cannot be connected to the signal line due to limitations on the signal specifications, then an EMI suppression filter should be used for the interface cable connection terminal.

■**Without EMI Filter**



■**With EMI Filter**



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# **2**  Suppressing EMI Noise Emission

## 2. EMI Suppression Filters

**Using EMI Suppression Filters**

The EMI suppression filters are connected to noise transmission lines to eliminate noise emitted from a noise source, or intruded from an external device. Therefore, the EMI suppression filters can be used for both noise suppression purposes: for suppression of noise emission, and for improvement of noise immunity. In order to prevent the noise on the filter input and output sides from being mixed with each other, the EMI suppression filters for suppressing noise emission should be located near the noise source, and those for improving noise immunity should be located near the device exposed to external noise.

If you intend to use an EMI suppression filter for a cable connection, it should be located at the root of the cable.



(a) Suppressing Noise Formation

(b) Improving Noise Immunity

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## **Suppressing EMI Noise Emission** **2**

### Effectiveness of EMI Suppression Filters Performance
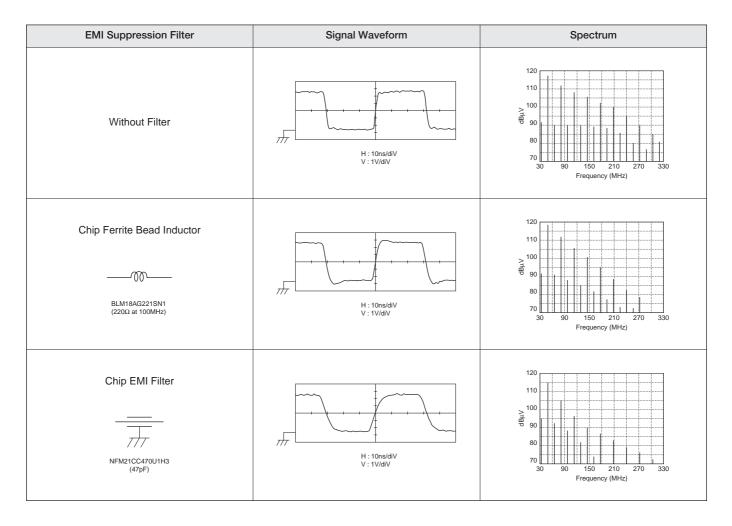
EMI suppression filters are generally classified into two types: inductor type and capacitor type. Chip ferrite beads are categorized as typical inductor type EMI suppression filters, and the chip EMIFIL® is categorized as typical capacitor type EMI suppression filters. Both types of EMI suppression filters are low pass filters, which eliminate unnecessary harmonics from digital signals.

The inductor type EMI suppression filter is connected to a signal line in series to suppress unnecessary harmonic current. The capacitor type EMI suppression filter is connected to a signal line and GND line, so that unnecessary harmonics are forced to flow into the GND line via the bypass capacitor.

We will explain how to use these EMI suppression filters on the following pages.

■**Test Circuit**



| EMI Suppression Filter | Signal Waveform | Spectrum |
|---|---|---|
| Without Filter | <br>H : 10ns/diV<br>V : 1V/diV |  |
| Chip Ferrite Bead Inductor<br><br>BLM18AG221SN1<br>(220Ω at 100MHz) | <br>H : 10ns/diV<br>V : 1V/diV |  |
| Chip EMI Filter<br><br>NFM21CC470U1H3<br>(47pF) | <br>H : 10ns/diV<br>V : 1V/diV |  |

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## 2  Suppressing EMI Noise Emission

### How to Use Inductor Type EMI Suppression Filters
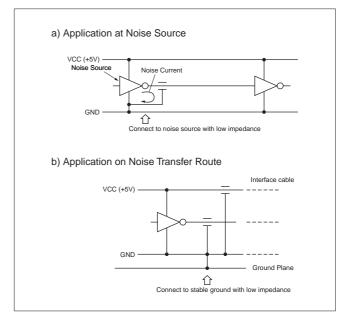
The inductor type EMI suppression filter (EMI suppression filter whose primary component is inductor "Examples : Ferrite bead inductor") should be inserted into a noise transmission line in series. When the EMI suppression filter is located near a noise source, it should be connected only to a signal line. When the EMI suppression filter is located at a distance from a noise source, it should be connected to all transmission lines, because noise may conduct through a power line and GND line as well as the signal line.

a) Using at Noise Source

B) Using on Noise Transfer Route

### How to Use Capacitor Type EMI Suppression Filter (1)

The capacitor type EMI suppression filter (EMI suppression filter that has capacitor built-in "Examples : Three terminal capacitors, EMI suppression filters for signal lines") should be inserted into a noise transmission line in series, and also connected to a GND line.

When the EMI suppression filter is located near a noise source, it should be connected to the GND terminal of the noise source at the minimum distance, so that a preferable noise return path can be established from the capacitor type EMI suppression filter to the noise source.

When the EMI suppression filter is located at a distance from a noise source, you should use a GND plane to intensify the GND condition in addition to the noise suppression component, because noise may conduct through the GND line as well as the signal line.

a) Application at Noise Source

Connect to noise source with low impedance

b) Application on Noise Transfer Route

Connect to stable ground with low impedance

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## Suppressing EMI Noise Emission **2**

**2**

### How to Use Capacitor Type EMI Suppression Filter (2)

These figures show examples of the pattern designs that locate the capacitor type EMI suppression filter near a noise source. The GND terminal of the EMI suppression filter and the GND terminal of the IC that serves as a noise source should be connected to the ground that covers the entire back surface of the PWB, so that a preferable noise return path can be established.

■**Good**
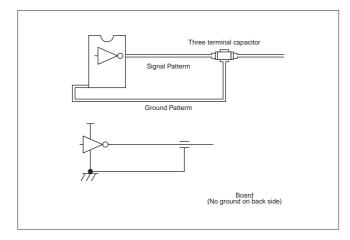
Filter's ground terminal is connected via a thru hole to the back side whose entire surface is grounded.
1. Ground's high frequency impedance is small
2. The signal pattern-to-ground pattern loop is small



■**Poor**

1. Impedance between filter's ground and IC's ground terminal large.
   (Little noise current is returned to the ground.)
2. The signal pattern-to-ground pattern loop is large.
   (Noise may be radiated from this loop.)
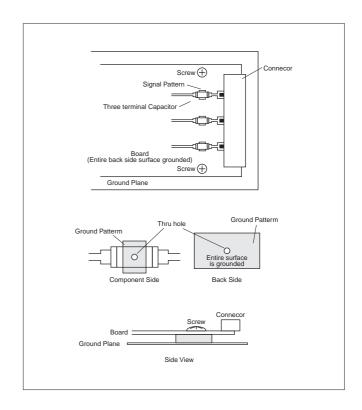


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## **2** **Suppressing EMI Noise Emission**

### How to Use Capacitor Type EMI Suppression Filter (3)

These figures show examples of the pattern designs that locate the capacitor type EMI suppression filter near an interface connector.

The EMI suppression filter should be placed as close as possible to the connector, and connected to the filter GND terminal on the back surface of the PWB. This filter GND terminal should be connected to the GND plane to intensify the GND condition.

### ■Good
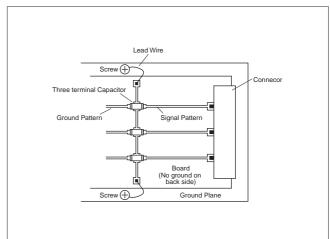
1. Signal pattern between three terminal capacitor and connector is shot.
   (Harder for noise to be induced signal pattern)
2. Filter's ground terminal is connected via a thru hole to the back side whose entire surface is grounded.
   (Ground pattern's high frequency impedance is small)
3. Ground pattern on the board and ground plane connected by screws.

### ■Poor

1. Signal pattern between three terminal capacitor and connector is long.
   (Noise induced to signal pattern)
2. Ground pattern has increased high frequency impedance.
3. Increased high frequency impedance between board's ground pattern and stable ground.
   (ground plane)





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## Suppressing EMI Noise Emission  **2**

## 3. Improved Ground Pattern

As a technique for suppressing common mode noise, we can consider intensification of the GND condition. When a signal return current flows through the GND line, a voltage applied to the GND terminal causes common mode noise. To suppress such voltage on the GND terminal, we must reduce the GND impedance between the signal sending and receiving ICs, with attention to the high speed signal in the circuit.
In order to prevent noise interference between circuit blocks, we must reduce the GND impedance between individual circuit blocks, so that the GND current from individual circuit blocks will not interfere with each other.

1. Ground impedance is reduced by making the ground pattern between the signal IC's input and output wide and short. This minimizes the potential difference relative to the ground.
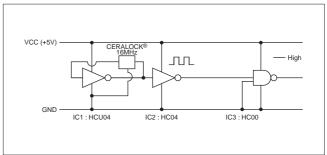


2. Common impedance is reduced by broadening the ground pattern to minimize cross talk between signal lines.



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# 2 Suppressing EMI Noise Emission

## Influence of Ground Pattern

We carried out an experiment to confirm variations in noise radiation level depending on changes in GND pattern width, and the results of this experiment are shown in the charts. When the GND pattern is provided only on the front surface of the PWB (although the original PWB has GND patterns on both the front and back surfaces), the noise radiation level is increased by 10dB or more. Furthermore, when the front GND pattern width is reduced and the gap between the GND pattern and the signal pattern is enlarged, the noise radiation level is further increased by approx. 10dB. As shown, as the GND pattern width decreases, the noise radiation level increases. To suppress the noise radiated from the PWB, inserting an EMI suppression filter into the signal line and providing a GND plane to intensify the GND condition, as described on the next page, are effective.

### ■Test Circuit



### ■Board Layout and Noise Radiation

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## Suppressing EMI Noise Emission **2**
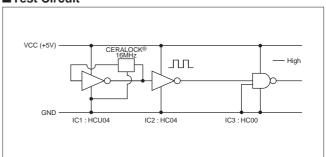
## Improved Ground Pattern with Ground Plane

### ■Test Circuit



## ■Board Layout and Noise Radiation

| | Board Layout | Radiated Noise |
|---|---|---|
| Initial |  |  |
| Ground Strengthening Only |  |  |
| EMI Suppression Filter Only |  |  |
| EMI Suppression Filter and Ground Strengthening |  |  |

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## 2  Suppressing EMI Noise Emission
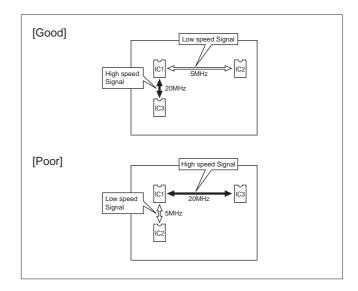
### 4. Changing Component and Pattern Layout
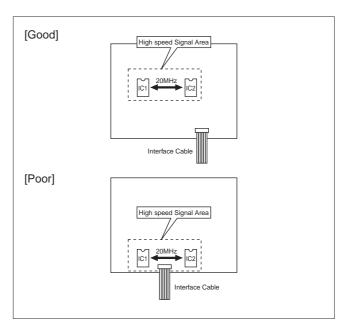
Even if a circuit is designed for a similar operation, the noise level varies depending on the component or pattern layout on the PWB. As shown in the experimental data on the following pages, the noise level increases as the signal frequency increases, or as the signal line is extended. Therefore, we can suppress the noise level by reducing the length of a high speed signal line with higher priority over other low speed signal lines.

If a circuit that may emit strong noise is located near an interface cable, the noise emitted from the circuit may conduct through the cable, resulting in radiation from the cable. To prevent such radiation noise, the high speed signal circuit that may emit strong noise must be located at as long a distance from the interface cable as possible.

1. Shorten shortening of high speed signal line to minimize radiated noise and common mode noise generation from signal line.
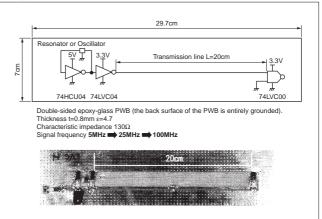


2. Separate high noise level circuit and cable to minimize noise coupling.

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## Suppressing EMI Noise Emission  2

### Influence of Signal Frequency

These charts show the variations in noise radiation level depending on changes in signal frequency. As the signal frequency increases, the spectrum interval increases, and the noise level also increases. The frequency range where the noise radiation is observed extends to higher frequencies.

### ■Experimental PWB



Double-sided epoxy-glass PWB (the back surface of the PWB is entirely grounded).
Thickness t=0.8mm ε=4.7
Characteristic impedance 130Ω
Signal frequency **5MHz** ➡ **25MHz** ➡ **100MHz**

### ■Radiated noise (actual measurement)



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## **2** **Suppressing EMI Noise Emission**

### Influence of Transmission Line Length

These charts show the variations in noise level depending on changes in transmission line length at the same signal frequencies.
You can see that the noise level increases, particularly at low frequencies, as the transmission line is extended.

■**Experimental PWB**



Double-sided epoxy-glass PWB (the back surface of the PWB is entirely grounded).
Thickness t=0.8mm ε=4.7
Characteristic impedance Z=130Ω

■**Radiated noise and signal waveform (actual measurement)**

Transmission line length L=5cm



Transmission line length L=10cm



Transmission line length L=20cm



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## **Suppressing EMI Noise Emission** 2

## 5. Influence of Signal Pattern Width

The charts show the variations in radiation noise level and waveform depending on changes in transmission line pattern width. As the transmission line pattern width reduces, the radiation noise level reduces. This phenomenon is probably because the current flowing through the line decreases as the characteristic impedance of the line increases.

Regarding the waveform, we can see that the ringing of the waveform is suppressed as the transmission line pattern width increases. It is probably because increasing the pattern width lowers the characteristic impedance of the transmission line, and when the line impedance is reduced to the IC's output impedance (approx. 20Ω in this example), the signal reflection is minimized.

Characteristic Impedance : Z
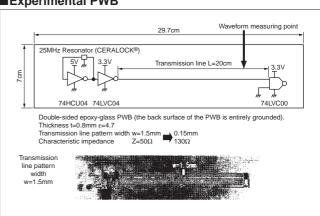
$$Z = \sqrt{\frac{L}{C}}$$

L : Inductance per unit length
C : Capacitance per unit length
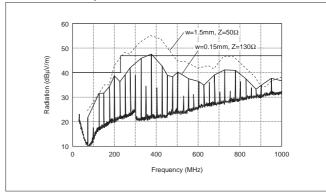
$$\text{Current } I = \frac{V_i}{Z} - \frac{V_r}{Z}$$

$V_i$ : Traveling wave voltage
$V_r$ : Reflected wave voltage

■**Experimental PWB**



Double-sided epoxy-glass PWB (the back surface of the PWB is entirely grounded).
Thickness t=0.8mm ε=4.7
Transmission line pattern width w=1.5mm ➡ 0.15mm
Characteristic impedance Z=50Ω ➡ 130Ω

Transmission line pattern width w=1.5mm
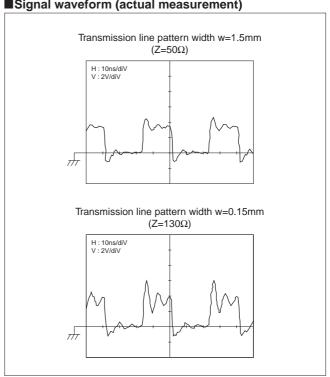
■**Radiated noise and signal waveform (actual measurement)**



■**Signal waveform (actual measurement)**

Transmission line pattern width w=1.5mm
(Z=50Ω)

H : 10ns/diV
V : 2V/diV

Transmission line pattern width w=0.15mm
(Z=130Ω)

H : 10ns/diV
V : 2V/diV

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## 2 | Suppressing EMI Noise Emission

**2**

## 6. Influence of PWB Thickness
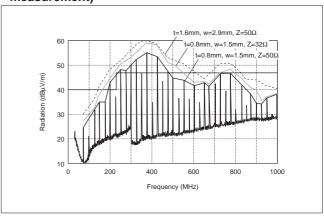
This chart shows the variations in radiation noise level depending on changes in PWB thickness.
When the PWB thickness and pattern width are changed simultaneously so that the same characteristic impedance can be obtained, the radiation noise level is lowered as the PWB thickness is reduced.

### ■Experimental PWB

29.7cm

7cm

25MHz Resonator (CERALOCK®)

5V    3.3V         Transmission line L=20cm              3.3V

74HCU04  74LVC04                                   74LVC00

Double-sided epoxy-glass PWB (the back surface of the PWB is entirely grounded) ε=4.7

| PWB Thickness | t=1.6mm | 0.8mm | 0.8mm |
| Transmission line pattern width | w=2.9mm | 1.5mm | 1.5mm |
| Characteristic impedance | z=50Ω | 32Ω | 50Ω |

Transmission line pattern width w=2.9mm

### ■Radiated noise and signal waveform (actual measurement)



t=1.6mm, w=2.9mm, Z=50Ω
t=0.8mm, w=1.5mm, Z=32Ω
t=0.8mm, w=1.5mm, Z=50Ω

Radiation (dBμV/m) vs Frequency (MHz)

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## Suppressing EMI Noise Emission  2

## 7. Shielding

### Shielding of Case

We will now explain the precautions for shielding a PWB. Generally, a shielding effect depends on reflection and absorption. However, when a PWB is shielded with a metal case, in the 30MHz or higher frequency range subjected to digital equipment noise regulations, reflection is more predominant than absorption. As a general shielding method, we should shield a PWB with a conductive material such as iron or aluminum.

A key point to shielding effect improvement is how to design the openings and gaps between connecting parts in the shielding case. To improve the shielding effect, we must increase the number of connecting parts in the shielding case, so that the longest side of the openings and gaps can be minimized.

The connecting parts in the shielding case must have low impedance, and must be in close contact with each other without clearance, Make sure that the metal surface of the shielding case is not coated with an insulating material.

■**Principle of Shielding**



■**Shield Point**

| | Good | Poor |
|---|---|---|
| **Opening Area** |  Intersperse smaller holes. |  |
| **Cover Connection** |  Use shorter intervals for low impedance connection. |  |

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## 2  Suppressing EMI Noise Emission

### Influence of Openings in Shielded Case

The charts show the variations in noise radiated from a digital circuit under various shielding conditions. On the assumption that a shielding case has a total of approx. 2500mm² in opening area, the opening dimensions change as shown above. From these measurements, we can observe a preferable shielding effect when the opening area is divided into small holes. However, the shielding effect is reduced markedly when the shielding case has a single rectangular opening.

| Shape of Opening Area | Noise Emission |
|---|---|
| ø20mm × 8 (2513mm²)<br> |  |
| 50mm × 50mm (2500mm²)<br> |  |
| 125mm × 20mm (2500mm²)<br> |  |
|  |  |

Test board is shielded in a metal case and measured for radiated noise using 1 meter method.
(Signal frequency : 25MHz)

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# **3** How to Select and Use EMI Suppression Filters
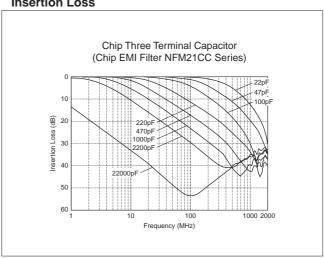
This chapter describes how to select EMI suppression filters for noise suppression, and how to use the EMI suppression filters effectively by referring to examples of EMI suppression filter applications in typical circuits.

## Relation between EMI Filters
## Noise Suppression Performance and Signal Waveform Distortion (1)
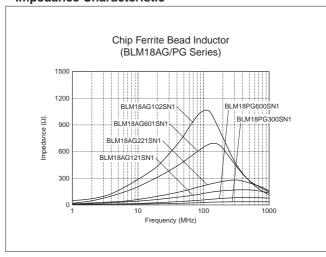
Generally, EMI suppression filters are low pass filters, which will distort the signal waveform while eliminating noise. Therefore, when selecting EMI suppression filters, we should pay attention to the signal waveform quality.

The noise suppressing effects of the capacitor type EMI suppression filters and the inductor type EMI suppression filters improve as the capacitance increases, and as the impedance increases, respectively. However, with an increase in noise suppressing effect, distortion of the signal waveform also increases.

Murata offers various types of EMI suppression filters, so you can select the optimum filters according to your intended applications.

## ■Example of Capacitor Type EMI Suppression Filter's Insertion Loss

Chip Three Terminal Capacitor
(Chip EMI Filter NFM21CC Series)

## ■Example of Inductor Type EMI Suppression Filter's Impedance Characteristic

Chip Ferrite Bead Inductor
(BLM18AG/PG Series)

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# **3** **How to Select and Use EMI Suppression Filters**

## Relation between EMI Filters
## Noise Suppression Performance and Signal
## Waveform Distortion (2)

These charts show examples of the signal waveform and harmonic spectra (cause of noise) measured in a circuit that uses a three terminal capacitor for a digital signal line. From these measurements, you can see that increasing the capacitance of the three terminal capacitor can improve the noise suppressing effect, but results in large distortion of the signal waveform.

### ■Test Circuit
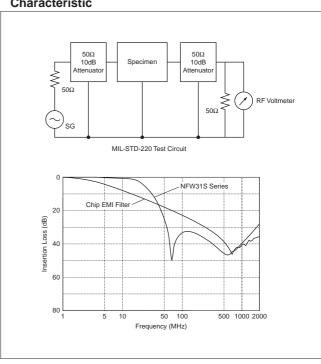


### ■Relation between EMI Suppression Filter's Noise Suppression Performance and Signal Waveform Rounding
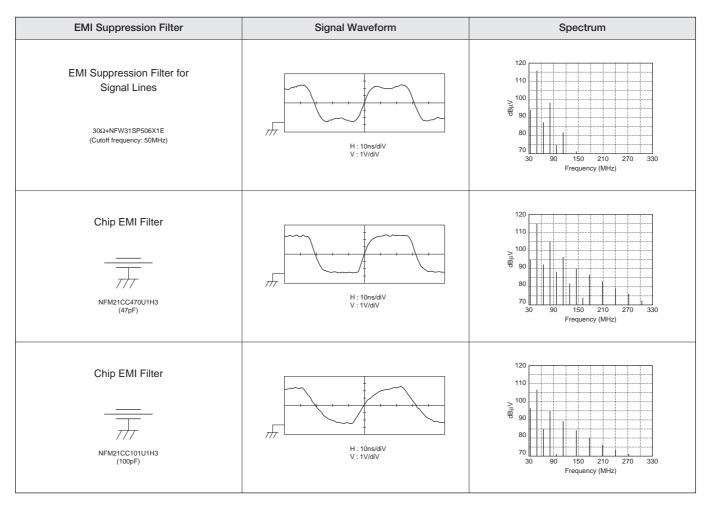
| EMI Suppression Filter | Signal Waveform | Spectrum |
|---|---|---|
| Without Filter |  H : 10ns/diV  V : 1V/diV |  |
| Chip EMI Filter  NFM21CC470U1H3  (47pF) |  H : 10ns/diV  V : 1V/diV |  |
| Chip EMI Filter  NFM21CC101U1H3  (100pF) |  H : 10ns/diV  V : 1V/diV |  |

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## How to Select and Use EMI Suppression Filters  **3**

### Relation between EMI Filters
### Noise Suppression Performance and Signal
### Waveform Distortion (3)

The EMI suppression filter for a signal line provides sharp frequency characteristics so that it can minimize distortion of the signal waveform while eliminating noise. We measured the signal waveform and harmonic spectra in a circuit that uses this EMI suppression filter for a digital signal line. The measurements are shown above, in comparison with the data obtained with the three terminal capacitor. From these measurements, you can see that the EMI suppression filter for a signal line can reduce the distortion of the signal waveform and provide a significant noise suppressing effect.
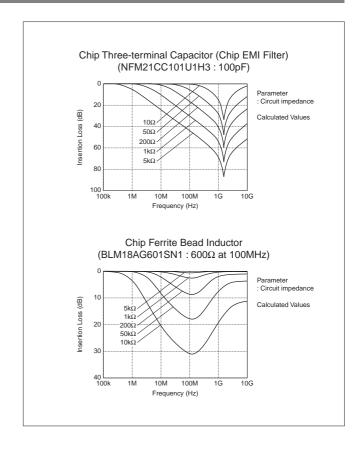
### ■EMI Suppression Filter's Insertion Loss Characteristic



MIL-STD-220 Test Circuit



| EMI Suppression Filter | Signal Waveform | Spectrum |
|---|---|---|
| EMI Suppression Filter for Signal Lines<br><br>30Ω+NFW31SP506X1E<br>(Cutoff frequency: 50MHz) | H : 10ns/diV<br>V : 1V/diV | |
| Chip EMI Filter<br><br>NFM21CC470U1H3<br>(47pF) | H : 10ns/diV<br>V : 1V/diV | |
| Chip EMI Filter<br><br>NFM21CC101U1H3<br>(100pF) | H : 10ns/diV<br>V : 1V/diV | |

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# 3   How to Select and Use EMI Suppression Filters

## 1. Circuit Impedance and EMI Suppression Filters Performance

EMI suppression filters' noise suppressing effect varies depending on the impedance of the circuit where the filter is mounted. Generally, the capacitor type and inductor type EMI suppression filters have significant noise suppressing effects in high impedance circuits and low impedance circuits, respectively. Using the capacitor type EMI suppression filter easily provides a relatively large noise suppressing effect. On the other hand, the inductor type EMI suppression filter is easy to mount, because it does not need to be connected to a GND line, and provides a stable noise suppressing effect.

Chip Three-terminal Capacitor (Chip EMI Filter)
(NFM21CC101U1H3 : 100pF)

Parameter
: Circuit impedance

Calculated Values

10Ω
50Ω
200Ω
1kΩ
5kΩ

Chip Ferrite Bead Inductor
(BLM18AG601SN1 : 600Ω at 100MHz)

Parameter
: Circuit impedance

Calculated Values

5kΩ
1kΩ
200Ω
50kΩ
10kΩ

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## How to Select and Use EMI Suppression Filters  **3**

## 2. Selecting Capacitor Type or Inductor Type EMI Suppression Filter

l. At Noise Source
(a) Capacitor type EMI suppression filter as primary
    device
  · Line with high circuit input or output impedance
  · Line with high noise level
    (Ex. Clock line; control bus line)

(b) Inductor type EMI suppression filter as primary
    device
  · Line with low circuit input or output impedance
    (Ex. Power supply line to which bus controller is
    connected)
  · Line with relatively low noise level
    (Because filter grounding is unnecessary and
    installation is simple)
  · Line requiring current control
    (Ex. Multiple lines that switch simultaneously and
    in which large current flows to the ground:
    Address/data bus; control bus)

2. Noise on Conductive Path
Use a combination of capacitor type and inductor type
EMI suppression filters.
  To suppress noise in a transmission line such as an
  interface cable connector, you should use the inductor
  type EMI suppression filter in combination with the
  capacitor type EMI suppression filter, because such a
  line needs a significant noise suppressing effect and,
  in most cases, cannot provide a stable GND condition.
  When using a combination of many capacitors and
  inductors, make sure that different types of
  components are adjacent to each other (i.e. the
  capacitors and inductors should be alternately
  connected).

**3**

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# 3  How to Select and Use EMI Suppression Filters

## 3. Examples of EMI Suppression Filter Use at Noise Source

### 1. Clock Line
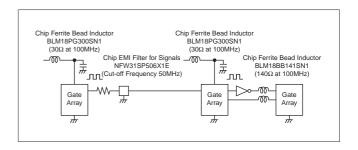
A clock signal has the highest frequency in a circuit. When the signal line is long, the clock signal may emit strong noise. Furthermore, since the signal frequency is close to the noise frequency, it is difficult to eliminate noise from a clock signal line while maintaining the signal waveform. Therefore, you should use the EMI suppression filter for the signal line that provides sharp frequency characteristics, or the chip ferrite beads inductor for high-speed signal lines to eliminate noise from the clock signal line.
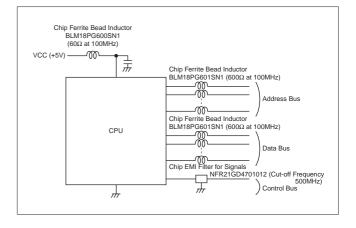
If the signal line can be shortened, you may use the chip ferrite beads inductor, because a relatively low noise suppressing effect is enough for the line.

To eliminate noise emitted from a power supply for an IC driving a clock signal, you should use a chip ferrite beads inductor in combination with a bypass capacitor.



### 2. Bus Line

Since many signals are simultaneously turned ON/OFF in a bus line, a large current flows through the power supply line and GND line instantaneously, causing noise interference. To eliminate such noise, it is effective to suppress the current flowing through the power supply line and GND line by reducing the current flowing through a signal line. For this purpose, you should use a ferrite beads inductor for each signal line. If a larger noise suppressing effect is required, you should use the chip EMIFIL® for a signal line that has internal resistance.

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## How to Select and Use EMI Suppression Filters **3**

## 4. Examples of EMI Suppression Filter Use on Conductive Noise Path

### 1. Signal Cable Connecting Section
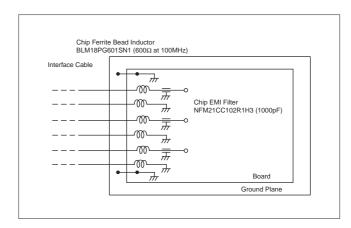
If a larger noise suppressing effect is required, you should use the chip EMIFIL®, or capacitor type EMI suppression filter, in combination with a chip ferrite beads inductor. If a relatively low noise suppressing effect is enough for the line, you may use just the chip ferrite beads inductor.
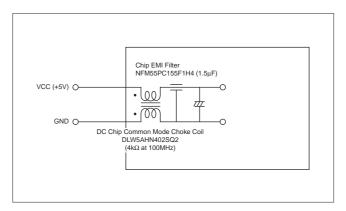
To utilize the capacitor type EMI suppression filter more effectively, you must connect the GND terminal of the EMI suppression filter to a stable ground. If a stable ground is not available, you should provide a ground plane to intensify the GND condition.



### 2. Power Supply Cable Connecting Section

For EMI noise suppression on a power supply line, the mode of the noise that is being conducted must be determined and an EMI suppression filter appropriate for the particular noise mode must be used. In a circuit with relatively stable ground, normal mode noise is the primary noise. In a circuit with unstable ground, common mode noise is also present.

When both normal mode and common mode noises exist, a measure that is effective against both must be taken.

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# **3** How to Select and Use EMI Suppression Filters

## 3. Power Supply Cable Connecting Section-2

Using the test board in Chapters 1 and 2, noise suppression was tested against power supply cables. This test board initially had measures against both normal mode and common mode noises using the following EMI suppression filters to reduce radiation of noise from power supply cable:
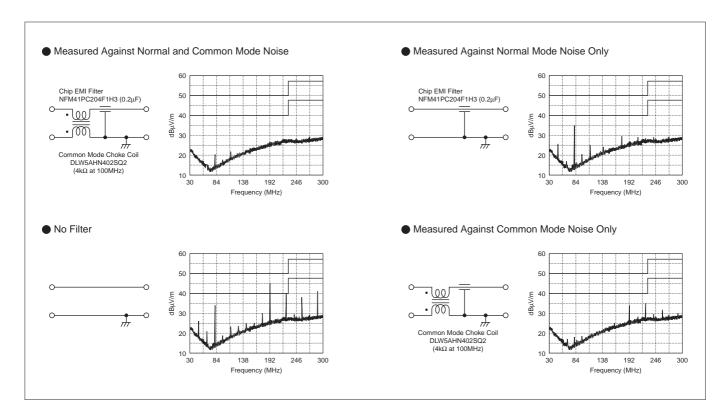
Against normal mode noise: Three terminal capacitor
(Chip solid EMI Filter)
Against common mode noise: Common mode choke coil

The test involved removing one of these EMI suppression filters, and the results were as indicated by the data shown above. The data shows that this board's power supply cable was radiating both common mode noise and normal mode noise.

■**Test Board**



● Measured Against Normal and Common Mode Noise

Chip EMI Filter
NFM41PC204F1H3 (0.2μF)

Common Mode Choke Coil
DLW5AHN402SQ2
(4kΩ at 100MHz)



● No Filter



● Measured Against Normal Mode Noise Only

Chip EMI Filter
NFM41PC204F1H3 (0.2μF)



● Measured Against Common Mode Noise Only

Common Mode Choke Coil
DLW5AHN402SQ2
(4kΩ at 100MHz)



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# 4   Differences in Noise Suppressing Effect Caused by Transmission Line Length

EMI suppression filters' noise suppressing effect varies significantly depending on the conditions of the transmission line between the input and output circuits, even if the same input/output circuits are used. This chapter shows examples of variations in a ferrite beads inductor's noise suppressing effect depending on the transmission line length and analyzes possible causes of the variations in noise suppressing effect.

To analyze the cause of variations, we measured the current distribution in the transmission line to examine the relationship between the measured current distribution and the ferrite beads inductor's noise suppressing effect.

At the end of this chapter, we will explain how to improve the noise suppressing effect when a single ferrite beads inductor cannot provide a sufficient noise suppressing effect.

## 1. Example of Change in Noise Suppressing Effect Depending on Transmission Line Length
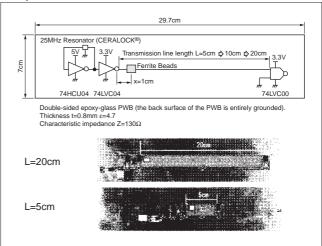
### Experimental PWB and Measuring Method

The PWB and noise measuring conditions used in this experiment are shown above. We prepared a digital signal with a frequency of 25MHz and measured the signal waveform and radiation noise level when the digital signal was flowing through the transmission line (micro strip line).
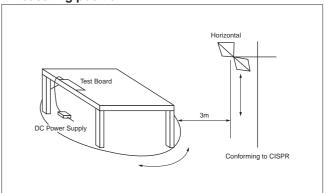
When a ferrite beads inductor is connected to this signal line, a decrease in the noise radiated from the signal line is defined as the ferrite beads inductor's noise suppressing effect.

We carried out this experiment to evaluate variations in noise suppressing effect by changing the transmission line length from 5cm to 20cm.

■**Experimental PWB**



Double-sided epoxy-glass PWB (the back surface of the PWB is entirely grounded).
Thickness t=0.8mm $\varepsilon$=4.7
Characteristic impedance Z=130$\Omega$

L=20cm

L=5cm

■**Measuring position**



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# 4  Differences in Noise Suppressing Effect Caused by Transmission Line Length

## Radiation Noise Measurement

These charts show the impedance vs. frequency characteristics of the ferrite beads inductor used as a sample and the radiation noise measurements. Although the initial noise level varies slightly depending on the transmission line length, the peak frequency and the peak noise level are almost constant. However, after connection of the ferrite beads inductor, the radiation noise level shows a remarkable difference depending on the transmission line length. In particular, a significant change is observed at a frequency of 375Hz, where the peak noise level is measured. With the 5cm transmission line, the noise level is reduced as much as 13dB. With the 20cm line, however, the noise level is reduced by only 2dB. From these measurements, we can see that the noise suppressing effect varies significantly depending on the transmission line length, even if the same ferrite beads inductor is used.

### ■Mounted Ferrite Beads Inductor

BLM18AG121S (120Ω at 100MHz)

### ■Radiated noise (actual measurement)

| | Before Mounting Ferrite Beads Inductor | After Mounting Ferrite Beads Inductor |
|---|---|---|
| L=5cm | | |
| L=10cm | | |
| L=20cm | | |

Change in Noise Suppressing Effect Depending on Transmission Line Length

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length  **4**

## 2. Analysis of Cause of Variations in Noise Suppressing Effect

### Analyzing Cause of Variations in Noise Suppressing Effect
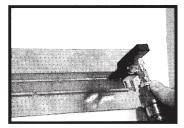
To analyze possible causes of variations in a ferrite beads inductor's noise suppressing effect depending on transmission line length, we measured the current and voltage distributions in the transmission line.

For the current measurement, we used a magnetic field probe and a spectrum analyzer and prepared a calibration PWB to derive a current correction coefficient.

For the voltage measurement, we used a voltage probe and a spectrum analyzer.
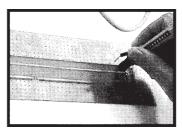
The charts above show the measurements of current and voltage distributions for a 20cm transmission line prior to connection of the ferrite beads inductor. As you can see from this example, the current and voltage in the transmission line vary depending on the measuring position in the line, and the current/voltage distribution also varies depending on the measuring frequency.

**4**

■**Current/voltage distribution measuring method**

Current distribution: Magnetic field probe
(Frequency band: 1MHz - 1GHz)
(To derive the correction coefficient,
a calibration PWB was prepared.)
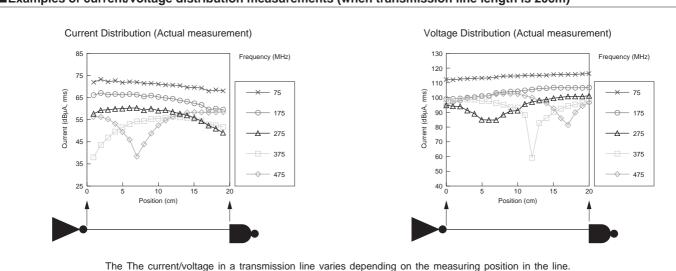


Voltage distribution: Voltage probe
(Frequency band: 2.5GHz)



■**Examples of current/voltage distribution measurements (when transmission line length is 20cm)**

Current Distribution (Actual measurement)



Voltage Distribution (Actual measurement)



The The current/voltage in a transmission line varies depending on the measuring position in the line.
Also, the current/voltage distribution varies depending on the measuring frequency.

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## 4  Differences in Noise Suppressing Effect Caused by Transmission Line Length

**4**
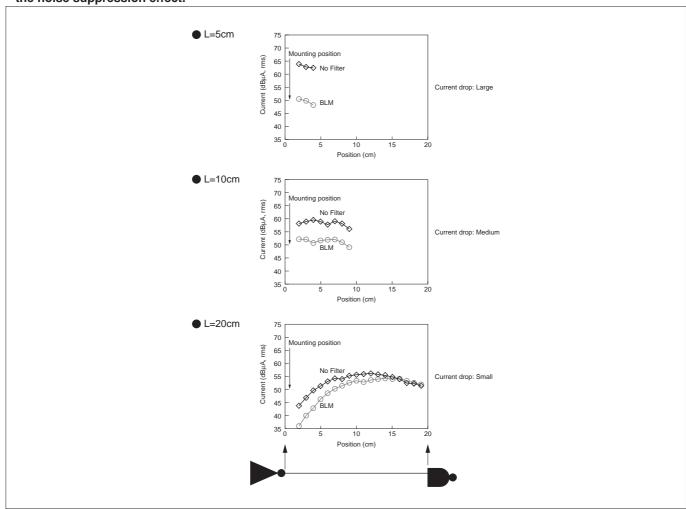
### Current Distribution Change after Connection of Ferrite Beads Inductor

Now, the current distribution prior to connection of the ferrite beads inductor is compared with the data after connection of the inductor. To compare the current distributions, our attention is focused on the data at 375MHz, because we observed a remarkable difference in the ferrite beads inductor's noise suppressing effect at 375MHz when the transmission line length on the prototype experimental PWB was changed. The charts above show the measurements of current distributions for individual transmission line lengths.

From these measurements, we can see that the current distribution at 375MHz, as well as the radiation noise level, is reduced as the transmission line is shortened. With the 5cm transmission line, the measured current is reduced as a whole and the peak current is reduced by 13dB, as seen in the radiation noise measurement result.

With the 20cm transmission line, however, there is no remarkable current drop, and the peak current is reduced by only 2dB, as seen in the radiation noise measurements.

■**375MHz Current Distribution (Actual measurement). Focusing on the frequency shows a remarkable difference in the noise suppression effect.**

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length **4**

## Analysis of Cause of Variations

We have learned that there is a relationship between a current distribution change and radiation noise change. We will compare the current distribution data for individual transmission line lengths before connection of the ferrite beads inductor.

With attention to the current distribution at the ferrite beads inductor mounting position, we observed a large current in the 5cm and 10cm transmission lines, where the ferrite beads inductor had significant noise suppression effects. On the other hand, with the 20cm transmission line, where the ferrite beads inductor's noise suppression effect is low, the current measured at the filter mounting position was the minimum value, and the peak current appeared at a distance from the filter mounting position or at a position slightly near the load.
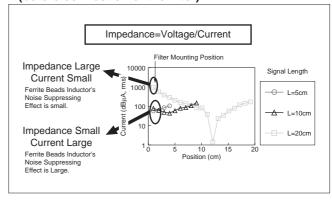
Then, we calculated the impedance by dividing the current value by the voltage value. The impedance at the filter mounting position in the 5cm and 10cm transmission lines was less than 100Ω. On the other hand, the impedance at the filter mounting position in the 20cm transmission line was approx. 1kΩ, which was extremely larger than the former value.

Since the ferrite beads inductor is an impedance component, it provides a significant noise suppressing effect when the impedance at the filter mounting position is small. However, when the impedance at the filter mounting position is large, it can hardly provide a sufficient noise suppressing effect. In the experiment using the 20cm transmission line, the impedance at the filter mounting position was as large as 1kΩ, although the ferrite beads inductor's impedance is 166Ω. Therefore, we conclude that the ferrite beads inductor cannot provide a sufficient noise suppressing effect in a 20cm transmission line.

■**Comparison of current values at filter mounting position (before connection of the filter)**



■**Comparison of impedance at filter mounting position (before connection of the filter)**



**4**

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# 4  Differences in Noise Suppressing Effect Caused by Transmission Line Length

## Difference in Peak Current Loss Depending on Transmission Line Length
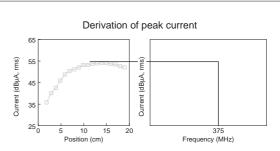
Through previous studies, we have learned that the current and voltage in a transmission line vary depending on the measuring position in the line, and the current and voltage distributions vary depending on the measuring frequency. Also, we have learned that the difference in the current/voltage distribution influences the ferrite beads inductor's noise suppressing effect.

In previous experiments, our attention was focused on the frequency of 375MHz, but as the next step, we will study how the noise suppressing effect changes depending on the measuring frequency.

This study is based on peak current loss, which is obtained by subtracting the peak current measured in a transmission line with a filter from the peak current measured without a filter at each measuring frequency. The peak current loss can be used as a reference value for evaluation of the filter's noise suppressing effect on radiation noise.

The charts above show the measurements of the peak current loss in 5cm, 10cm and 20cm transmission lines. From these charts, we can see that the frequency at which the ferrite beads inductor's noise suppressing effect becomes low varies depending on the transmission line length.
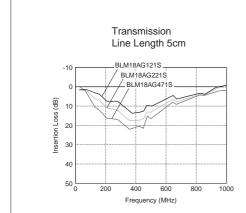
### ■Peak Current Loss (Definition)



Derivation of peak current
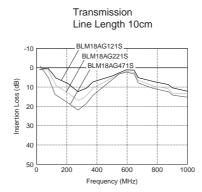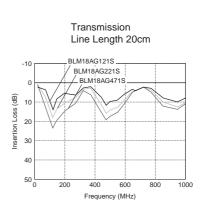
Peak current loss = Peak current measured without filter - Peak current measured with filter
(Used as a reference value for evaluation of the filter's noise suppressing effect)

### ■Peak current loss measurement result



The frequency at which the ferrite beads inductor's noise suppressing effect becomes low varies depending on the transmission line length.

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length  **4**

## Influence of Transmission Line Length on Ferrite Beads Inductor's Noise Suppressing Effect

The table lists the frequencies at which the ferrite beads inductor on the prototype experimental PWB can hardly provide a sufficient noise suppressing effect.
Assuming that the ferrite beads inductor is used for a general C-MOS digital circuit, the measurements suggest a strong possibility that the ferrite beads inductor provides a sufficient noise suppressing effect at 1GHz or lower frequencies in the 5cm transmission line. If the transmission line becomes longer, however, the frequencies at which the ferrite beads inductor can hardly provide a sufficient noise suppressing effect will be more clearly observed.

**4**

### ■Examples of the Frequencies at which Ferrite Beads Inductor's Noise Suppressing Effect becomes Low

| Transmission Line Length | | |
|---|---|---|
| 5cm | 10cm | 20cm |
| 1GHz | 600MHz | 350MHz<br>700MHz |

(When the Ferrite Beads Inductor is Used for a C-MOS Digital Circuit)

The Ferrite Beads Inductor Noise Suppressing Effect

When the Transmission Line Length is 5cm or Less  ⇨  The Ferrite Beads Inductor can Easily Provide a Sufficient Noise Suppressing Effect at 1GHz or Lower Frequencies.

When the Transmission Line is Longer than 5cm  ➡  The Frequencies at which the Ferrite Beads Inductor cannot Provide a Sufficient Noise Suppressing Effect are Clearly Observed.

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## 4 Differences in Noise Suppressing Effect Caused by Transmission Line Length

## 3. How to Improve Noise Suppressing Effect

### How to Improve Noise Suppressing Effect Method 1 : Considering Ferrite Beads Inductor Mounting Position

In a general C-MOS digital circuit, we have learned that the ferrite beads inductor may hardly provide a sufficient noise suppressing effect depending on the transmission line length. We will now discuss how to improve the noise suppressing effect to cope with such a case.

From the results of previous studies, we have learned that the ferrite beads inductor's insufficient noise suppressing effect is caused by the minute current at the ferrite beads mounting position. We then carried out the following experiment, assuming that changing the ferrite beads mounting position to the peak current point can improve the noise suppressing effect.

In this experiment, we used a 20cm transmission line and paid attention to the noise level at 375MHz.

375MHz Current Distribution
(Transmission Line Length 20cm : Actual Measurement)

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length  **4**

## Measurement Result on Shift of Ferrite Beads Inductor Mounting Position
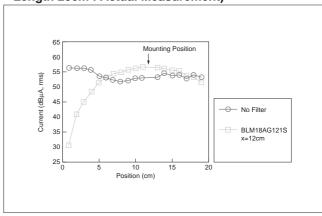
These charts show the radiation noise level measurements when shifting the ferrite beads inductor to the peak current point at a frequency of 375MHz. Contrary to our expectation, the radiation noise level measured at 375MHz is higher than the initial value. To examine the cause of this phenomenon, we measured the current distribution at 375MHz. The charts also show the current distribution measurements. When the ferrite beads inductor is moved away from the transmission terminal, the current flowing through the transmission line between the ferrite beads inductor and the transmission terminal becomes large, so we consider that it is a cause of the increased radiation noise level.

Taking such a phenomenon into consideration, we should, in most cases, mount the ferrite beads inductor close to the transmission terminal in order to improve the noise suppressing effect.

■Radiation Noise (Transmission Line Length 20cm : Actual Measurement)

Mounting Position : x=1cm
(Transmission terminal)

Mounting Position : x=12cm
(Current Peak Point)

The Radiated Noise Level is Increased

■375MHz Current Distribution (Transmission Line Length 20cm : Actual Measurement)

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## 4  Differences in Noise Suppressing Effect Caused by Transmission Line Length

### Correction of Method 1 : Noise Suppression Using Several Ferrite Beads Inductors

When a ferrite beads inductor is mounted to the peak current point (at 12cm distance from the transmission terminal) to suppress the current at 375MHz, the current flowing through the transmission line in the upstream of the ferrite beads inductor increases. To suppress the increased current, the same ferrite beads inductor is mounted to the transmission terminal in addition to the peak current point. The current distribution measurement is shown in the chart above. The peak current is reduced by 7dB from the value measured without the filter.
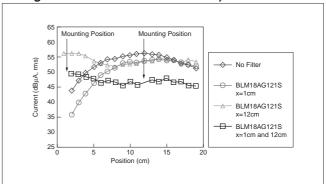
Also, we evaluated the noise suppressing effect in terms of the noise radiation level. When ferrite beads inductors are mounted to both the transmission terminal and peak current point, we can see that the radiation noise level at 375MHz is reduced by 7dB from the value without the ferrite beads inductor.

The radiation noise is 3dB lower than the value with a ferrite beads inductor with approx. twice the impedance mounted to the transmission terminal.
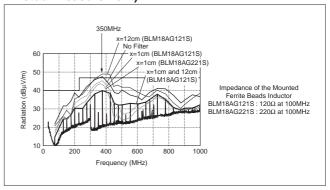
From these results, we can see that mounting ferrite beads inductors at two points (transmission terminal and peak current point) can provide a sufficient noise suppressing effect, even if a single ferrite beads inductor with higher impedance cannot provide a sufficient noise suppressing effect.

This corrective method is not intended for general use because it needs the step of finding the peak current point. However, it can be applied to a case where only the ferrite beads inductor can be used (a capacitor cannot be used) due to limitations on current consumption.

■375MHz Current Distribution (Transmission Line Length 20cm : Actual Measurement)



■Radiation Noise (Transmission Line Length 20cm : Actual Measurement)

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length  **4**

## How to Improve Noise Suppressing Effect Method 2 : Application of Capacitor

We will now discuss the second method.
At the frequency of 375MHz that we have mentioned so far, the ferrite beads inductor cannot provide a sufficient noise suppressing effect because of the large impedance at the filter mounting position. In such a case, a bypass capacitor works effectively to lead the noise current from the transmission line into the ground by reducing the impedance between the transmission line and the ground. We will now consider applying a capacitor.

■**375MHz Impedance (Transmission Line Length 20cm: No Filter)**



■**Function of the Capacitor**



The Bypass Capacitor Leads Noise Current into the Ground.

**4**

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## **4** **Differences in Noise Suppressing Effect Caused by Transmission Line Length**

**4**

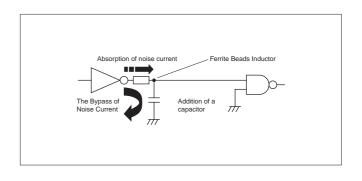### Considering Addition of a Capacitor

After removing the ferrite beads inductor, we mounted a capacitor with the relatively small capacitance of 10pF. The capacitor's noise suppressing effect was observed at some frequencies, but could not be observed at other frequencies.

A ferrite beads inductor provides a significant noise suppressing effect when the impedance at the mounting position is low. On the other hand, a capacitor provides a significant noise suppressing effect when the impedance at the mounting position is high. Therefore, in this experiment, we mounted a ferrite beads inductor in combination with a capacitor, where they could provide a significant noise suppressing effect in a wide frequency range.
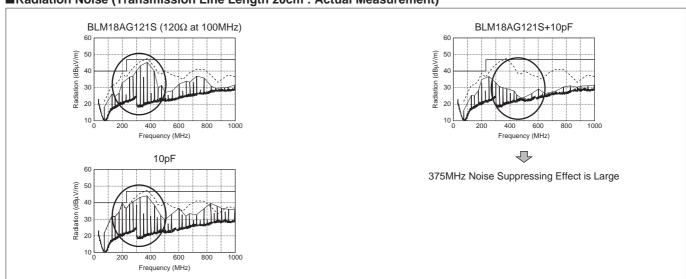
The radiation noise level at 375MHz was reduced by 18dB from the value without the filters.

Thus, we can see that the combined use of a capacitor and a ferrite beads inductor provides a significant noise suppressing effect when a single ferrite beads inductor alone cannot. Also, we confirmed the waveform obtained with the combination of a ferrite beads inductor and a capacitor, in comparison with the waveform obtained with a single ferrite beads inductor.
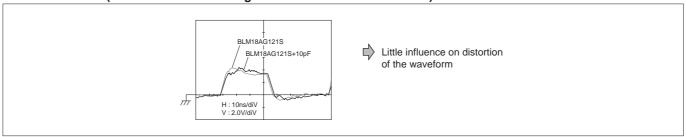
Since the additional capacitor's capacitance is relatively small (10pF), it has little influence on distortion of the waveform at a signal frequency of 25MHz.



■**Radiation Noise (Transmission Line Length 20cm : Actual Measurement)**



BLM18AG121S (120Ω at 100MHz)



BLM18AG121S+10pF



375MHz Noise Suppressing Effect is Large



10pF

■**Load waveform (Transmission Line Length 20cm : Actual Measurement)**



BLM18AG121S
BLM18AG121S+10pF
H : 10ns/diV
V : 2.0V/diV

⇨ Little influence on distortion
of the waveform

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# Differences in Noise Suppressing Effect Caused by Transmission Line Length  **4**

## 4. Cause of Variations in Ferrite Beads Inductors Noise Suppressing Effect and How to Improve the Noise Suppressing Effect

This chapter shows examples of variations in a ferrite beads inductor's noise suppressing effect depending on the transmission line length, and analyzes possible causes of the variations. We measured the current distribution in the transmission line to examine the relationship between the current distribution and the ferrite beads inductor's noise suppressing effect. From the measurements, we can see that the current/voltage in the transmission line varies depending on the measuring position in the line, and that the current/voltage distribution also varies depending on transmission line conditions such as the line length. Through the comparison of the current distribution data at individual frequencies and the ferrite beads inductor's radiation noise suppressing effects, we can see that the ferrite beads inductor can hardly provide a sufficient noise suppressing effect at the frequency where the current at the ferrite beads inductor mounting position is minimized. To cope with such a case, we consider that the following methods are effective for improving the noise suppressing effect:

1) Mount ferrite beads inductors to both the transmission terminal and the peak current point.
2) Mount a ferrite beads inductor in combination with a capacitor.

⚠Note  Please read rating and ⚠CAUTION (for storage, operating, rating, soldering, mounting and handling) in this PDF catalog to prevent smoking and/or burning, etc.
This catalog has only typical specifications. Therefore, you are requested to approve our product specifications or to transact the approval sheet for product specificaions before ordering.

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1. Export Control
   〈For customers outside Japan〉
   Murata products should not be used or sold for use in the development, production, stockpiling or utilization of any conventional weapons or mass-destructive weapons (nuclear weapons, chemical or biological weapons, or missiles), or any other weapons.
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2. Please contact our sales representatives or product engineers before using the products in this catalog for the applications listed below, which require especially high reliability for the prevention of defects which might directly damage to a third party's life, body or property, or when one of our products is intended for use in applications other than those specified in this catalog.
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   ③ Undersea equipment　　　　④ Power plant equipment
   ⑤ Medical equipment　　　　　⑥ Transportation equipment (vehicles, trains, ships, etc.)
   ⑦ Traffic signal equipment　　⑧ Disaster prevention / crime prevention equipment
   ⑨ Data-processing equipment　⑩ Application of similar complexity and/or reliability requirements to the applications listed in the above

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