PROBE SET
MODEL PS-400

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WARRANTY

All equipment manufactured by **Com-Power Corporation** is warranted against defects in material and workmanship for a period of two years from the date of shipment. Com-Power Corporation will repair or replace any defective item or material if notified within the warranty period.

You will not be charged for warranty service performed at our factory. You must, however, prepay inbound shipping costs and have a return authorization.

This warranty does not apply to :

a) productss damaged during shipment from your plant or ours.
b) products which have been improperly installed.
c) products operated outside their specifications.
d) products which have been improperly maintained.
e) modified products.
f) normal wear of material.
g) calibration.

Any warranties or guarantees, whether expressed or implied, that are not specified set forth herein, will not be considered applicable to any equipment sold or otherwise furnished by Com-Power Corporation. Under no circumstances does Com-Power Corporation recognize or assume any liability for any loss, damage or expense arising either directly or indirectly from the use or handling of products manufactured by Com-Power Corporation, or any inability to use them separately or in combination with other equipment or material.

The warranty is void if items are shipped outside the United States, without prior knowledge of Com-Power Corporation.

Warranty Limitations

The above warranty shall not apply to defects resulting from improper or inadequate maintenance by the buyer, unauthorized modification or misuse, operation exceeding specifications, or improper site preparation.

SAFETY PRECAUTIONS

The Near Field Probe Set PS-400 is designed to locate sources of electromagnetic energy for use in an EMI or electronics test laboratory. These sources are, generally, very weak RF sources of low voltage circuits. Therefore, the probes' sensing tips are insulated for isolation from low voltage circuitry only. Care should be taken not to exceed the voltage ratings. In addition, if the probes show any sign of wear or insulation break down, its use should be immediately stopped. The BNC connectors on the probes have exposed metal, and its contact to any active circuit must be avoided.

When probing equipment with high voltage or high RF energy in the equipment, only personnel trained in working with such circuits should be permitted. All necessary safety precautions must be taken to avoid shock hazards or RF exposure while testing or examining such equipment.

Maintenance and Service:
There are no user serviceable parts inside the probes. Call the factory if service is required.

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About this Manual

This manual provides instructions for using the Probe Set.

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If You Need Assistance

If you encounter problems while using the model PS-400, contact Com-Power Corporation at (714) 528-8800.

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General Information

1

This section includes the following:

1.1 Introduction

This Section contains general performance and background information on PS-400 Probe Set. A more detailed functional description is provided in Section 2 and Section 3.

1.2 General Description

The Probe Set PS-400 consists of three probes. One of these probes is a magnetic field (or H-field) sensing probe. The other two are electric field (or E-field) sensing probes. These probes were specifically designed to find EMI noise sources in electronic systems. They generate an output voltage which can be observed with a 50 ohm RF instrument such as a spectrum analyzer or an RF receiver.

The H-field probe is designed to detect the presence of magnetic field and minimize the effect of electric field on its output. A loop at the end of the probe acts as its sensor, therefore, this probe is also called a "loop probe". This loop is shielded for minimizing E-field pick up.

The two E-field probes were designed to sense the presence of electric field and to minimize the effect of magnetic field. One of these probes, is called the "Tip Probe" because of its fine tip. It is extremely sensitive to the position of the tip relative to the source. The second E-field probe is called "broad band" probe because it is sensitive over a relatively wider frequency range. The probe has a rounded end and has a higher amplitude sensitivity than the fine tip probe. These two probes are complementary in function as explained later in section 2.

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The EMI noise suppression is required for several agencies in USA as well as around the world. This noise is usually RF in nature and very low (of the order of 60 dB microvolts per meter) at about a 3 meter distance from the equipment under test (EUT). These probes help to achieve compliance quickly, economically and efficiently for electronic systems by allowing to probe close to circuits. Guessing and over designing is avoided by finding the exact noise sources in systems and suppressing the noise at the source.

The procedure for investigating electronic enclosures and circuits is described in Section 2.

The theory of operation of the probes is described in Section 3. This section also has a brief description on how to suppress the noise, once the source is located using the probes.

1.3 Specifications

The specifications of the Probe Set PS-400 are listed in Table 1-1.

1.4 Equipment, Accessories, and Documents Supplied

The Equipment, accessories, and documents supplied with the Model PS-400 Probe Set are as follows:

- a) Set of three probes
- b) User's Manual
- c) Storage box

Table 1.1. Specifications

	H-Field Probe	Broadband Probe	Tip Probe
Frequency Range	0.06-100 MHz	20-1000 MHz	30-600 MHz
Dielectric Breakdown	1KV typical	1KV typical	1KV typical
Temperature Range	0 to 40^o C	0 to 40^o C	0 to 40^o C
Connector Type	BNC	BNC	BNC

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Operating Procedure

2

This section contains the following:

a) Introduction
b) Set up
c) Application

2.0 Introduction

This Section describes how to set up the test system for the probing and how to use the probes to find the noise sources in the system.

It is assumed that prior to locating the noise source the emissions tests are performed at a distance of 1 meter, 3 meters or 10 meters using an antenna. These distances are generally considered far field. When the level of emissions at a perticular frequency is high as compared to the specification, the engineer needs to reduce the emisions. However, he may have no clue as to where the energy is leaking in the system or what could be done to reduce the emissions. The first step in reducing the emissions would be to know what part of the circuit is causing the emissions to be high. This section describes how to use the probes to find this source.

2.1 Equipment Set Up

This paragraph describes how to set up the test equipment for finding the noise source. The set up for the EUT is described in Para. 2.2.

2.1.1 Test Equipment Set Up

The probes are used with a spectrum analyzer or a receiver functioning as an EMI meter. For the rest of the discussion, we will refer to it as a spectrum analyzer. A suitable probe is selected as described in section 2.1.2 below. This probe is connected directly to the spectrum analyzer or through a preamplifier to improve the noise level. A preamplifier may be necessary specially with the tip probe. The tip probe is designed for maximizing the

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sensitivity to position of the tip and not the amplitude sensitivity. The connection to the input of the preamplifier is made using a short (typically not longer than 1 meter) 50 ohm coaxial cable. Also, the connection from the output of the preamplifiers to the spectrum analyzer input is made using a 50 ohm coaxial cable.

The spectrum analyzer is set to the frequency of the signal to be investigated. Set its span set to about 1 MHz and the same resolution bandwidth as that of the far field measurement.

2.1.2 Probe Selection

The probes are selected according to the function required to be performed. The H-field probe is more sensitive to a magnetic field whereas the E-field probes (the tip probe and the broadband probe) are more sensitive to an electric field. The electromagnetic fields have electric as well as magnetic components. A particular field may be strong near the source, and accordingly the source may be called electric or magnetic. As the field travels away from the source, this distinction starts to fade as shown in Figure 2.1. The region where this distinction is not possible is referred to as the far field. That is, in the far field the ratio of the E and H field strength is a constant equal to the characteristic impedance of the medium of propagation. For air or free space this equals 120π or 377 ohms. The near field and far field distinction occurs at the approximate distance of $\lambda / 2\pi$, where λ is the wavelength. Of course, this distance is dependent on the frequency of the wave.

Understanding the behavior of a field (see figure 2.1) is important for two reasons. First, it indicates that near the source the field is strongly electric or magnetic and the E-field or H-field probe can be used accordingly. Second, it indicates that the ratio of E to H field strength varies rapidly near the source. Even though it is not apparent in figure 2.1. The E-field decays inversely proportional to the cube of the distance near the E-field source and the H-field decays inversely proportional to the cube of the distance near the H-field source.

The user may try all probes to find out the most suitable probe, however, generally, the E-field probes are most suited for the digital signals (clocks, data, address, chip select, read, write, etc.). The H-field probe is most suitable for the power supply circuits, high current circuits or enclosure evaluation. When its not known whether the source is electric or magnetic, the probes can

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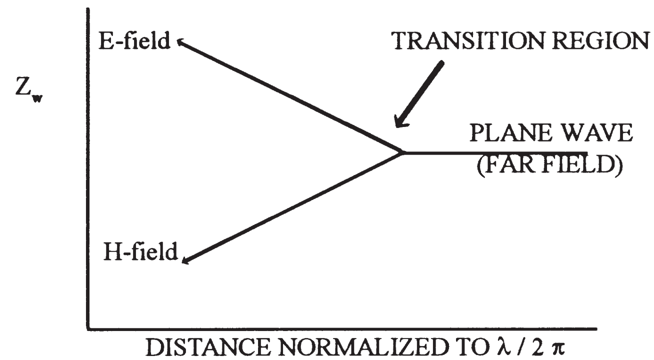

Figure 2.1 Wave Impedance (Z_w) vs Distance

also to be used to determine the nature of the source. The first step is to measure the fall-off rate of E and H-field as you move the probe away from the source. If the fall-off rate of E-field is higher (measured using the E-Field probe) as compared to fall-off rate of H-field (measured using the H-Field probe). Then the field must be E-Field. If the fall-off rate of H-field is higher than the E-field then the field must be H-Field. These rates are relative rates of the readings (in dB) as a function of position taken with the same probe. Therefore, the absolute value of the field or probe calibration is not required.

Broadband Probe

The rounded end probe in the probe set is the broadband probe. This probe is usable over the frequency range of 20-1000 MHz. It has good amplitude sensitivity and is used for electric field sources. Such sources include logic circuits, controllers, microprocessors, clocks lines, address lines or control lines. This probe is used in conjuction with the fine tip probe to locate the noise source to a single trace or signal pin. The broadband probe is used first, to quickly identify the general area (usually about one square inch) because of its amplitude sensitivity. After that the fine tip can be used in this area to locate the exact pin as described below.

Fine Tip Probe

As the name implies, this probe has a fine tip. This probe has narrower frequency range (30 MHz - 700 MHz), than the broadband probe. Its fine tip in combination with sensitivity to tip position is very useful in locating a single trace or pin on an IC. In many systems, the highest emission is due to just a few traces (even one or two signal traces on some). Once these traces are discovered, the overall far field emissions can be reduced by working on their circuit as described in Section 3.2.

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H-Field Probe

This probe has a loop at the sensing end, so it is also referred to as "loop probe". This probe is used for H-field sources, which are produced by stronger currents (as compared to voltages) and larger loop areas covered by their current paths. Since all circuits generate magnetic as well as electric fields, the electric and magnetic probes are interchangeable to some extent. In some cases, whether to use an electric field or magnetic field probe is more suitable can be determined by trying.

2.2 EUT Set Up

The equipment to be tested is generally set up as specified in the regulatory agency document. These documents describe the details including the exact placement of EUT as well as the support equipment, the operating modes and the software they perform. Still, some aspects may not be mentioned and the test engineer may have to select an arbitrary mode. However, it is important to remember that the emission will depend on the exact set up of operating mode of the EUT as well as the support equipment. Therefore, during the investigation, the EUT mode must be carefully controlled to represent the final qualification test. That includes clock speed, software, function etc.

The obvious exception to this rule is the enclosure which must be opened to access the circuit boards for probing. Such changes must be taken into account to avoid any error in conclusions.

2.1.4 Probing a Digital Circuit Card

It is assumed that the frequency or frequencies of problem is known from the far field tests performed using antennas. Begin the probing with the spectrum analyzer set to the highest emission frequency. (or the particular frequency of interest, which may be one of the highest emissions). The near field probing only reveals the problem circuit which is the main source of noise. Without this information one may be just be guessing or shooting in the dark trying to reduce the noise by shielding the entire system or putting several suppression devices on the board. However, the near field improvements have to be finally verified in the far field because that is required by the specifications.

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Once the regions with the highest reading(also called the hot points or hot spots) on the board are found with the broadband probe, the tip probe is used to locate the highest reading trace or signals. This reading will increase as the noisiest trace is approached from either side. The reading will be two, three or more dB higher at the noisiest pin or trace compared to its adjacent trace. For example, the reading is 51, 54, 57, 60, 56 ,53 and 50 dB uV on the adjacent pins. The noisiest pin in this group reads 60 dBuV reading. If the other hot spots were at least 10 dB lower that the highest (60 dB in our case), one may conclude, as an engineering simplification that this is the noise source in the system. Proceed to eliminate that problem as described in section 3.

Note that this is a simplification and an approximation, where the effect of length of trace is not considered. In general, there may be more than one noisy signal in the system. In that case, to determine the most likely cause of problem, the coupling capability of a trace needs to be considered. That is because the far field emission is the combined effect of (a) noise coupling from the noise source to its adjacent conductors and (b) these adjacent conductors radiating that energy into the space around the equipment. We improve our approximation considerably by including the effect of length. For example, if we have another hot spot with the pins in the group (call this group B) reading 50,52, 55, 57, 54, 51, and 47 dB uV. Here, the pin reading 57 could also be a noise source. We can compare the groups A and B as follows:

An approximate weight can be assigned to their ability to transmit by taking into account their lengths. The effect of length is linear or 20 log L, where L is the length of the trace, as shown below.

	Group A	Group B
Reading	60 dBuV	57 dBuV
Length	2 inches	10 inches
Correction	6 dB	20 dB
Final effect	66 dBuV	77 dBuV

This example shows that the trace reading 57 dB in group is likely to be stronger source of noise than the one reading 60 dB in group A. This same approach is used when more than two groups are encountered. The correction for the length is relative so, any units of length may be used as long as the same units are used for all traces.

Even though the above example shows that the short trace is less likely to be a problem it depends on how short it is. Let us add another group C in the above example. This group has readings 65, 68, 70, 72 , 75, 72, 69 dBuV. If the noisiest trace in this group is also only 2 inches long, it would yield the following final effect.

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	Group A	Group B	Group C
Reading	60 dB	57 dB	75 dB
Length	2 inches	10 inches	2 inches
Correction	6 dB	20 dB	6 dB
Final effect	66 dB	77 dB	81 dB

This indicates that the group C trace is the likely to be the strongest source of noise. We say this as a probability because other factors such as (a) trace isolation or (b) adjacent trace's capability to pick up the noise, also affect the far field strength. For this reason, all hot locations may need to be evaluated. Of course, one has the option of coming back to the other traces, if modifications on one do not reduce the emissions in the far field.

Go to Section 3, after the noisy trace or traces are determined. Section 3 explains how to make modifications to the signal circuit to reduce the energy leaking out and the theory behind it. The solutions given there is generic for digital circuits only. Even for other circuits, solutions may be similar and it is hoped that the design engineer who is more familiar with his circuit than the writer, will be better equipped to find the solution, once the source is known.

2.4 Probing An Enclosure

Even the enclosure for shielding electronic equipment can be probed with the probe set. Noise leaking out from the shielding enclosure is investigated using the H-field probe. That is because as an electromagnetic wave passes through the shield, the magnetic field leakage is more predominant near the enclosure.

The probe will show higher emissions (a) near an opening or (b) near a seam. The seams are any joints where lack of electrical contact between two overlapping parts of the enclosure prevent electrical currents to flow. Compared to the opening, seams are difficult to detect just by observation because they are not always so obvious. The seams may be formed by nonconductive paint or by nonconductive surface treatment such as anodizing.

The leakage due to an opening or a seam is dependent on the frequency of the wave as well as the length of the opening (and not the area of the opening).

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Theory of Operation

3

This chapter explains the following:

a) Overview
b) Theory of Operation

3.0 Overview

This section describes the theory of operation of the probes.

3.1 Theory of Operation

The Near Field Probes pick up strong localized field near the source. Once source the located, potential design problems that are causing the emissions to be high can be investigated. The specific funtion of each probe in the probe set in locating the noise source is described below.

Broadband Probe and Fine Tip Probe

The broadband probe is usable over the frequency range of 20-1000 MHz and the tip probe has frequency range of 30 MHz - 700 MHz. The broadband probe has good amplitude sensitivity and the tip probe has excellent sensitivity to tip position. They are both used for electric field sources produced by circuit voltage. Such sources include logic circuits, controllers, microprocessors, clock lines, address lines or control lines. The broadband probe is used first to quickly identify the general area (usually about one square inch) because of its amplitude sensitivity. After that the fine tip can be used in this area to locate the exact trace or pin.

H-Field Probe

The loop probe is used for H-field sources, which are produced by stronger currents (as opposed to voltages) and larger loop areas covered by their current paths, All circuits have voltages as well as currents to a varying degree, therefore, the electric and magnetic probes are interchangeable to some extent and the most suitable probe can be determined

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by experimentation. A large energy reading does not imply that any perticular probe is more suitable. If an E-field probe gives a larger energy reading, it could mean the source has strong E-field or that the probe has a better sensitivity at that frequency than the H-field probe.

3.2 Suppressing Noise

The techniques of suppressing noise can be as simple as reducing the circuit voltage or adding a series resistor. In this section only some simple techniques utilized for digital circuits on multilayer printed circuit board (PCB) are discussed. (If a two layer board has too much emissions, utilizing a multilayer board, employing ground plane with transmission line structure will help reduce the noise). Following is a limited discussion of a broad subject. More information can be found in the references given at the end of the section.

3.2.1 Transmission Line

When a ground plane and power plane are added to a two layer printed circuit board, the noise is reduced, because the signals have a transmission line path in the 4 layer PCB. When a signal travels along a trace, the energy is in the space around the conductor and its return path. With a four layer board, this return path is generally right next to the signal. A transmission line is formed when this space between the trace and its return path is not shared by other signals. That is what eliminates cross talk. However, just adding a ground and power plane does not guarantee a transmission line structure, one should make sure that the reference plane (ground) should always be close to the signal trace.

Any trace has relatively noisier and quieter locations on it. These can be discovered by just moving the E-field probe along its path. These hot spots along the trace also reveal the reasons for the energy leakage. The signal output pin and the trace end show high readings because there may be high reflections due to impedance mismatch.

Mismatch at the source: For commonly used digital circuits (TTL and CMOS) the low level output impedance (typically about 5 ohms) is much lower than the trace impedance which is about 50 to 70 ohms. This mismatch and the corresponding reflection coefficient is high. Adding a series resistor near the source would minimizes the mismatch and the reflections. This would reduce total noise emitted from the trace.

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Mismatch at the End: The commonly used digital circuits (TTL and CMOS) also have termination mismatch at the end of the traces because the trace impedance is of the order of 50 to 70 ohms, whereas the input of the gate is of the order of a few hundred ohms. This problem can be solved by adding a parallel termination to the load at the end of the trace. Since these device families can not handle a load of the 80 ohms, a series combination of the resistor and approximately 100pf capacitor is used (see Figure 3.1).

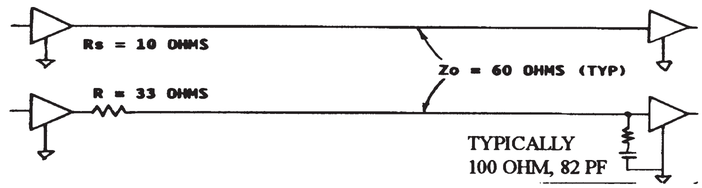

Figure 3.1, Line without termination and line with series and parallel termination.

Mismatch at the Vias: Even vias (also called feed throughs) on a trace change impedance. Probing near the via can verify if excessive emissions near a via exists. Vias cause problems specially for higher frequencies (30 MHz clocks and above). At frequencies above 100 MHz, special effort has to be made to avoid the bad effects of vias. For such high frequency signals the preferred trace layout is shown in figure 3.2.

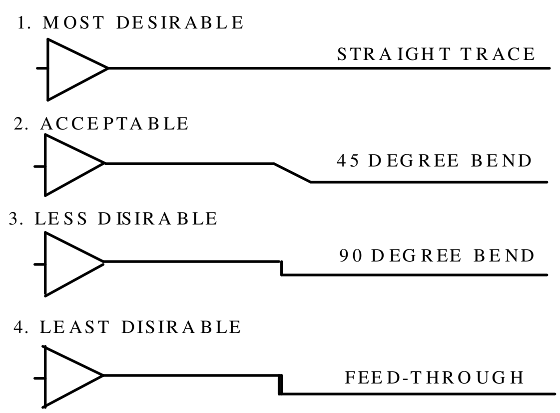

Figure 3.2, Prefered trace layout

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Mismatch due to Stubs: Stubs are the locations on the trace where the trace divides into two or more directions. The impedance can not be maintained at a stub because all line impedances will be observed in parallel. This can be avoided by connecting all loads in daisy chain fashion. See figure 3.3.

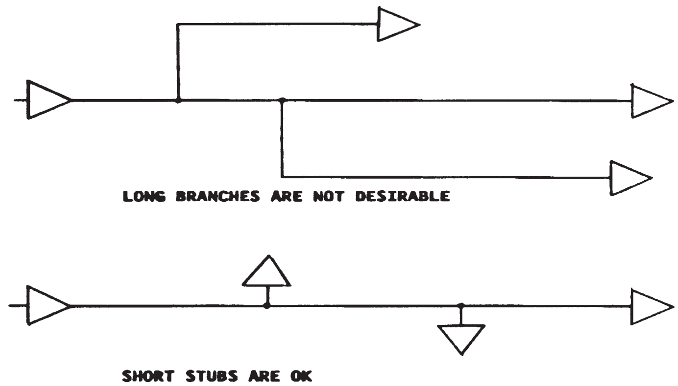

Figure 3.3 Stub Mismatch

References:

Some of the references on the subject of transmission lines are given below. It is hoped that these will be useful to you on reducing the noise from digital circuits.

1. ECL Design Handbook - Robert Blood, Motorola semiconductors 1988

2. Microcomputer Interfacing - Harold Stone, Addison-Wesley Publishing 1982

3. EMC Design Seminar Notes - Compatible Electronics, 1992

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