APPLICATION NOTE
42W-5850

PREVENTING SAMPLING HEAD OVERDRIVE AND STATIC DAMAGE

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INTRODUCTION

Sampling Technique

For making many high-speed scope measurements at or above 1 GHz, the only method is sampling. Sampling methods extend the bandwidth range by taking samples of a repetitive signal over a period of time and representing this sampled signal with a lower frequency signal. Only the input stage or sampling head sees the input signal frequency. After the input stage, the reconstructed signal passes through relatively low bandwidth amplifiers.

Sampling Heads

Although sampling heads are a relatively small piece of the sampling system, they are one of the most important parts. They are the input signal section of the sampling system. The sampling head is connected to the input signal. When it is gated, the sampling head passes part of that signal to the scope as a sample. Therefore, the sampling head helps to determine the system's input characteristics. Operating input voltage range, maximum input signal and dc voltage, and system rise time and bandwidth all depend on the sampling head. Figure 1 shows a typical sampling head.

Sampling heads contain a diode bridge or gate at the input. A strobe generator causes the diodes in this bridge or gate to conduct at intervals long enough to take samples of the input signal. Once these samples are taken, they pass through the lower frequency, less critical circuits to form the reconstructed display.

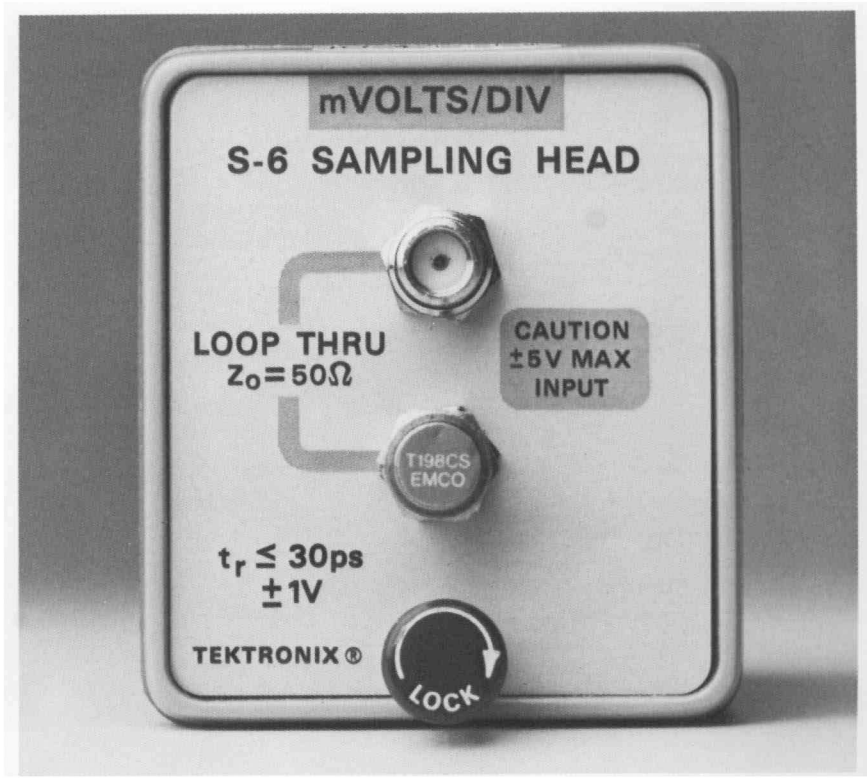

Figure 1. Type S-6 Sampling Head. Note terminated input.

SAMPLING HEAD LIMITATIONS

Signal Overdrive

The most critical and sensitive components in a sampling system are the bridge or gate diodes used in the head. These Schottky diodes are extremely susceptible to damage from overdrive signal or dc voltages and static discharge. You must take signal and static precautions to avoid damage or destruction of these critical components.

If the diodes are not destroyed, but merely damaged, the sampling system may still be useable. However, the diode and instrument life may be shortened, and performance will most likely be degraded. System rise time and signal aberrations often change as a result of damage to the sampling bridge or gate diodes.

You should always be aware of the input voltage to any sampling system. Never exceed the maximum input voltage rating of the head in use. For Tektronix sampling heads this voltage is + or − 5 volts dc or 10 volts peak-to-peak ac up to 10 MHz. Voltages above this rating can cause permanent damage or degrade performance. Sampling heads are calibrated to an input of + or − 1 volt. Signals that exceed this operating voltage will not permit a valid display.

Sampling heads with 50 ohm inputs are more likely to be damaged than those with high impedance inputs. High impedance heads offer current limiting because the signal must pass through input resistors before it goes to the bridge or gate diodes. In heads with 50 ohm input, the signal is coupled directly to the diodes.

Static Electricity

The signal that you apply to a sampling head input is easy to check. With little effort, you can know exactly what you are applying to the head before you connect it. Static, on the other hand, is much more difficult to control and thus presents a tougher problem to solve. Static is always present, occurring any time two materials contact and separate. A static charge can be generated any time there is no static control, even for an instant.

Any item at a work area or elsewhere can easily attain potentials high enough to cause damage. In fact, people are the biggest hazard, often attaining potentials high enough to damage most sampling heads. The S-1, S-2, and S-4 can be damaged by static potentials above 400 volts, the S-6 by potentials above 100 volts with the head input unterminated. The S-3A and S-5 are less susceptible to static damage because of their higher input impedance.

STATIC HAZARDS

Static build-up can occur on just about any object, including all the items you may use to operate or service the sampling head. Tools, cables, connectors, soldering equipment, other test equipment, and anything else on or around the bench can cause trouble.

Bench clutter can be a major cause of electrostatic discharge (ESD). Items such as plastic or styrofoam cups, candy wrappers, plastic trash can liners, plastic notebook covers, and even people's clothing are major causes of ESD damage to sampling heads.

The single major cause of ESD damage is people. The human body can store up to 35,000 volts of electricity and, in a manufacturing environment, charges up to 10,000 volts are common. Most often we are not aware of this charge. The threshold of feeling the discharge is about 3,500 volts, and the threshold of seeing it is about 5,000 volts. When you consider that sampling head damage can occur with as low as 100 volts of discharge, the static charge on a person handling the sampling head is a major concern.

Consider the following example of a person making contact with an S-6 Sampling Head input. The average person has a capacitance of about 160 picofarads. Assume this person is charged to 15,000 volts, which is not uncommon. The total energy (watt seconds) can be calculated as follows:

$$\text{Energy (watt seconds)} = \frac{(\text{capacitance})(\text{voltage})^2}{2}$$

$$\text{Energy} = \frac{(160 \times 10^{-12})(15 \times 10^3)^2}{2}$$

Energy = 18 milliwatt seconds

This does not sound like a lot of energy until you consider that the S-6 diode junction is about 1×10^{-7} square centimeters. This is a very small junction area. Figure 2 is an input sampling gate from an S-6 Head.

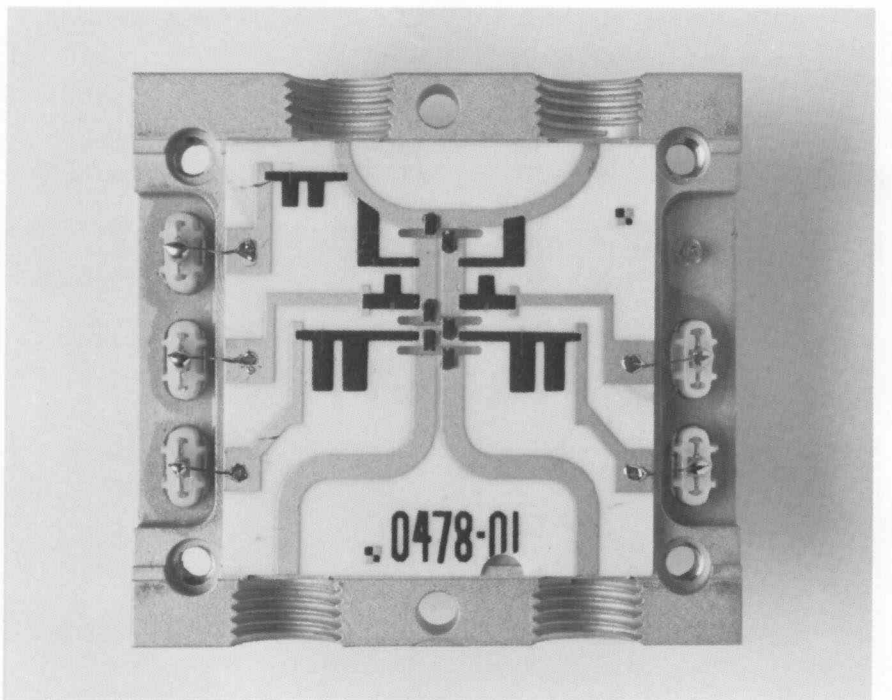

Figure 2. Input sampling gate diodes from an S-6 Head.

The power density per square centimeter can be calculated as follows:

$$\text{Power density} = \frac{\text{Energy}}{\text{junction area}}$$

$$\text{Power density} = \frac{18 \times 10^{-3}}{1 \times 10^{-7}}$$

Power density = 180,000 watt seconds per square centimeter

This is a huge amount of power. When the S-6 diodes are reverse biased, the power concentration can be as much as 1,000 times this amount because of the break down tunneling effect. This raises the power density to an incredible 180 mega-watt seconds.

Silicon melts at 200 degrees Celsius. Because the thermal mass of the S-6 diode junction is so small, applying this much power will cause instant vaporization of all or part of the junction.

AVOIDING STATIC DAMAGE

When determining the method to be used to avoid static damage, the materials involved can be thought of as conductors or non-conductors. Conductors are those materials that conduct electricity and if grounded will discharge. Non-conductors are those materials that do not conduct electricity and will not discharge when grounded.

To avoid static damage from conductors, a path to ground must be provided. This is done by using various conductive materials such as grounded floor and table mats, wrist straps, protective bags, approved trash can liners, stool covers, sleeve protectors, and shoe grounding straps. Static shielding bags and electrically conductive foam, boxes, containers, bins, and trays should be used when transporting static sensitive items. Figure 3 pictures several of the conductive items that can be used to protect your sampling heads.

Three of the most important of these are the table mat, floor mat, and wrist strap. The conductive table mat provides a surface that is free of static charge, and it also removes the static charge from conductive items placed on it. The conductive floor mat drains static charge from people approaching the work bench as they step on the mat. If the person is wearing rubber soled shoes, then

shoe grounding straps should be used. The wrist strap provides a permanent path to ground to prevent static build-up while working at the bench. The strap contains a one megohm resistor for a safe rate of charge removal equal to the rate of charge generation. Wrist straps should be grounded to the conductive table mat.

The best way to avoid damage from non-conductors is to avoid using them whenever possible. Plastic and styrofoam items should be kept away from the work area and static generating clothing should not be worn. To remove the charge from non-conductors that cannot be avoided, ionized air blowers should be used. Figure 4 shows a proper bench setup to avoid ESD while working on sampling heads.

Precautions

Once the work area is in order, there are several other measures you can take to prolong the life of your sampling system. The following measures are very important to avoid costly repairs.

1. Momentarily ground cables or other devices, before connecting them to the head input, to discharge any electrostatic charge.

2. Avoid touching the center conductor of cables or probe at the head input. This often occurs in TDR applications where circuit connections are made with alligator clips and other exposed connectors.

3. Terminate the head input when not in use. This is especially important with the type S-6 Head because it is more susceptible to damage from static discharge.

Figure 3. Various materials and devices used for static control. (Photo courtesy of The SIMCO Company.)

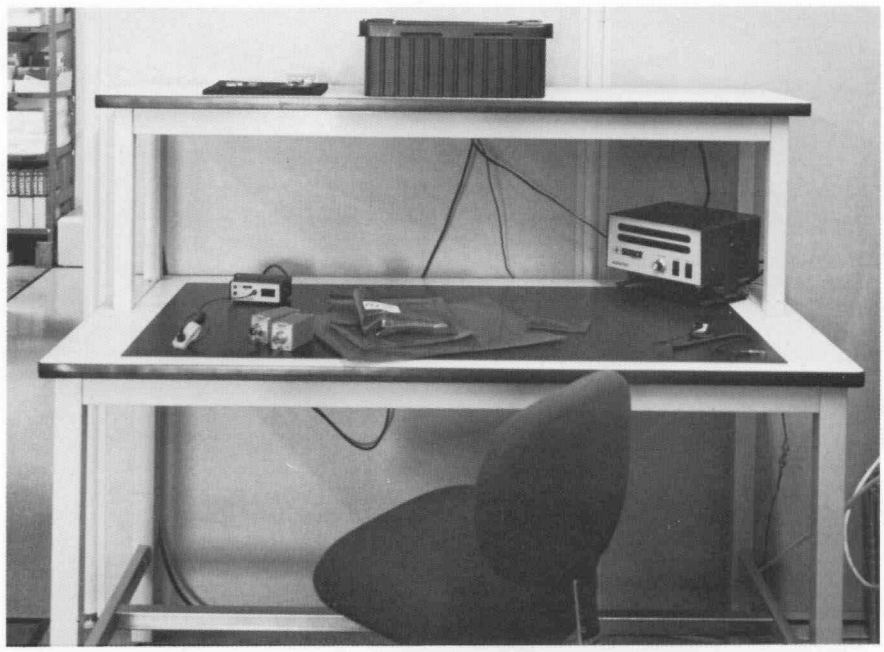

Figure 4. Work bench setup for static control. (Photo courtesy of The SIMCO Company.)

SUMMARY

Sampling scopes overcome the bandwidth and amplitude limits of conventional scopes. Signals above 1 GHz require sampling techniques to make many of the standard scope measurements.

Sampling heads provide the means for coupling high frequency signals to less critical circuits for processing and display. Plug-in sampling heads also provide versatility to satisfy a wide range of signal measurement needs.

The sampling head contains some very critical circuits and sensitive components to handle these kind of signals. Because of this, some special precautions should be used when operating and working on sampling heads. You will want to use special care with these high performance instruments. This will prolong their life and maintain the kind of performance you expect from a Tektronix sampling system.

If you do need service for your sampling instruments, we recommend you send them to a Tek Service center. Tektronix can expertly service your sampling heads and has flexible service programs for repair and calibration of all Tek sampling instruments. If you choose to repair and calibrate them yourself, Tek can provide technical assistance.

For further information and help with static control, the 3M Company offers a wide range of products and has static analysts at worldwide offices to provide training, problem evaluation, and other help. The 3M toll free number is 800-328-1368.

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