A New Electrical Overstress (EOS) Test for Magnetic Recording Heads

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Abstract – Electrical overstress (EOS) damage to magnetic recording heads due to repetitive, sinusoidal, low voltage noise is studied for the first time. A test method is described and used to measure the failure voltage and current for various combinations of signal connections from 200 kHz to 1 GHz. A resonance at 320 MHz, where the current flow increases dramatically and causes severe sensor damage at only 550 mV, was observed. A lumped-element SPICE model is developed and used to extend the experimental measurements. It is concluded that it is important to measure and understand the effect of low voltage, high frequency noise transients on extremely ESD sensitive devices.

I. Introduction

Connection of static sensitive devices to ground during handling and processing is a standard and accepted electrostatic discharge (ESD) control practice. However, when “ground” is the chassis of an automated tester with repetitive, low voltage but high frequency “noise” transients, device damage due to electrical overstress (EOS) can result [1].

Many real-life manufacturing process steps can expose magnetic head assemblies to voltage transients that can exceed the device failure level. Inadequate grounding and electrically-noisy tools is one cause for EOS exposure. EOS damage is possible when two or more of the multiple inputs of a device are connected to “ground” points with transients at different voltage levels or phase. It is not uncommon to observe several volts of high-frequency noise on ground that is otherwise proved to be adequate for ESD and safety purposes. An analytical study of the impact of such exposure and the factors influencing damage is therefore important.

This paper defines a simple EOS test method for studying the susceptibility of a magnetic recording heads to damage from low-voltage, high-frequency signals. A SPICE model is developed to further understand the current flow. While the setup is used to measure the EOS failure of magnetic recording devices, the concept of testing EOS damage thresholds can be applied to any extremely ESD sensitive device.

II. Device Model

Figure 1 shows a simplified lumped-element model for a recording head on a suspension and shows the resistive and capacitive coupling between the suspension, slider, shields, reader and writer. The recording head has six locations for transient voltage input: suspension, slider body, and the pairs of reader (Rd+ and Rd-) and writer (Wr+ and Wr-) inputs. If two or more of these six inputs have a net voltage, V_n, connected across them, a current $I(\omega)= V_n(\omega)/Z(\omega)$ will result, where Z is the impedance between the two terminals and ω is frequency of the noise voltage. The

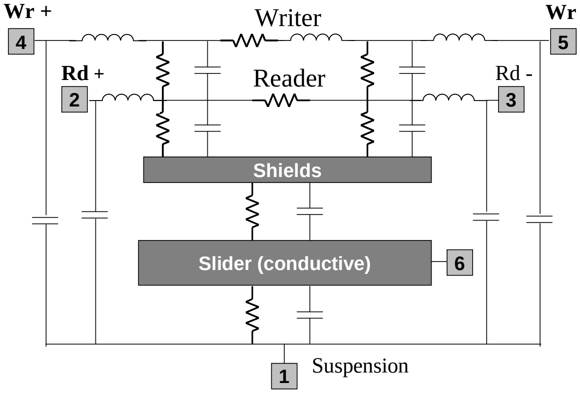

Fig.1. Simplified model for a recording head on suspension.

current flow through the device will depend on the impedance in the current path and the amplitude of the noise voltage. Note that, even if the two device inputs are *capacitively* coupled, noise transients can still result in significant current flow through the device at higher frequencies. Thus, current flow and device damage will in most cases depend strongly on frequency.

For example, when the noise source is connected across the reader (Rd+ to Rd-), the impedance of the head will be dominated by the purely resistive (R) and inductive (L) components, and almost all of the input current will flow through the read sensor. Conversely, when the noise source is connected across one input of the reader and the suspension (Rd+ to suspension), a series RLC circuit is formed. At low frequencies, the impedance of an RLC circuit is high and dominated by the capacitive reactance ($1/j\omega C$). At high frequencies, the impedance is also high, but is dominated by the inductive reactance ($j\omega L$). In between, a resonance occurs with a peak in the current flow. Note that there are multiple current paths for current flow and only the fraction of the current flowing *through* the read sensor will contribute to sensor heating and melting damage.

III. Experimental Setup

Figure 2 shows a schematic representation of the EOS experimental setup. An Agilent E4421B 3 GHz sinusoidal signal generator was used to simulate the harmonics in high-frequency ground noise. A TEKTRONIX CT-6 current probe with a 2 GHz bandwidth was used to measure the total current. While Fig. 2 shows the connection between one reader input and the suspension (Rd+ to suspension), testing was also performed across the reader inputs (Rd+ to Rd-).

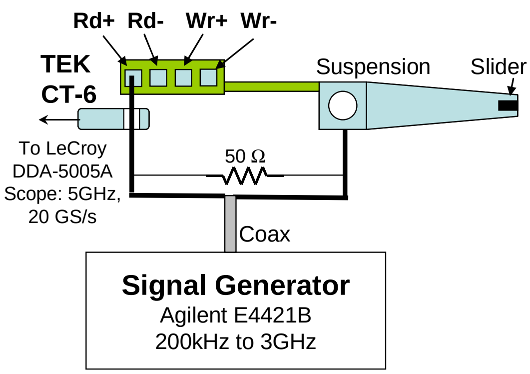

Fig. 2. Schematic representation of the experimental setup.

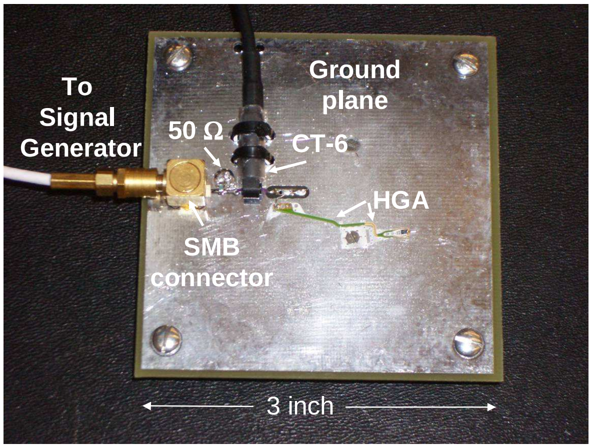

Fig. 3. Picture of custom PCB designed for EOS testing.

Figure 3 shows a picture of the custom 3in x 3in printed circuit board (PCB) that was designed specifically for this high frequency EOS testing. The signal generator output was connected to the SMB connector, which was followed by the 50 ohm surface mount terminating resistor and wire through the CT-6 current probe to make connection to a device input. Hard disk drive recording heads with GMR sensors designed for an areal density of 60 Gb/in^2 on head gimbal assemblies (HGA) were used in this study.

IV. Results

A. Experimental

Figure 4 shows the total current into the HGA vs. frequency using a 130 mVrms sinusoidal waveform for two different signal connection cases. In one case, the signal was connected across the Rd+ and Rd- inputs, and for the other case, the signal was

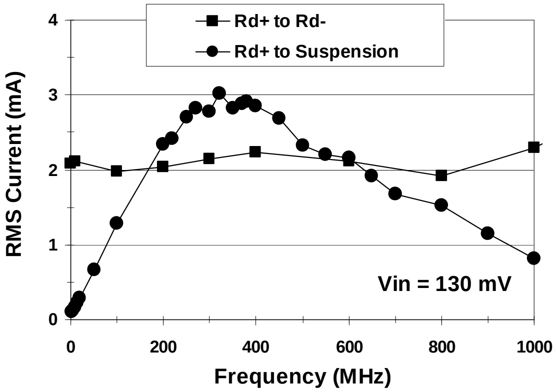

Fig. 4. Input current vs. frequency for signal connected across reader (Rd+ to Rd-) and across reader input and suspension (Rd+ to suspension).

connected across Rd+ and suspension. The two connection cases show dramatically different current vs. frequency. When the signal was connected across Rd+ to Rd-, the current vs. frequency behavior is relatively flat. For this connection case, the circuit is basically an RL circuit, with an impedance that is constant at low frequencies (R) and has a reactive component which increases linearly with increasing frequency (jωL). In this case, the inductance is small, so it contributes negligible impedance up to 1 GHz. In contrast, when the signal is connected across Rd+ and the suspension, the current peaks at 320 MHz and falls off dramatically at lower and higher frequencies. This behavior is consistent with an RLC circuit with a resonance at 320 MHz. Note that the current at resonance is slightly larger than the Rd+ to Rd- case, with the same input voltage.

At some current level through the sensor, the layers in the GMR sensor heat up sufficiently to melt, which results in an increase in read sensor resistance [2]. In the testing shown in Fig. 4, the input voltage was purposely kept below this damage threshold. To determine the damage threshold, the frequency was fixed and the signal voltage was increased further. The sinusoidal signal was turned on for 1 second, shut off, and then the resistance was measured. A resistance increase of 1% was taken to indicate failure.

Figure 5 shows the GMR sensor resistance vs. input voltage for two different heads with almost equal resistance, at the resonance frequency (320 MHz). For one head, the input signal was connected across the two reader inputs (Rd+ to Rd-). For the other head, the signal was connected across the reader input and suspension (Rd+ to suspension). Note the increase in resistance for each head as the voltage was increased, signifying sensor damage and melting similar to that seen during ESD testing [2]. The damage voltage threshold for Rd+ to Rd- (Rd+ to suspension) was 375 mVrms (560 mVrms). For the Rd+ to Rd- case, the damage current was 7.5mA. Figure 5 shows that the sensor can be damaged when the signal is connected across a reader input and the suspension. The failure level is only 50% higher than when the signal is connected directly across the two reader inputs (Rd+ to Rd-). While most ESD testing and control focuses on the voltage across the two read sensor inputs, EOS testing shows that sensor damage can occur when high-frequency transients are applied across a reader input and the suspension.

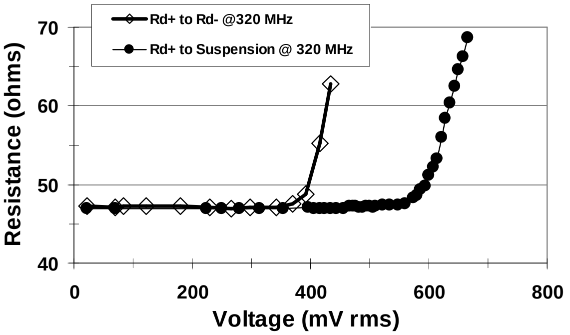

Fig.5. GMR sensor resistance vs. input voltage for two different heads. Sinusoidal source set at 320 MHz. The resistance increase indicates sensor damage.

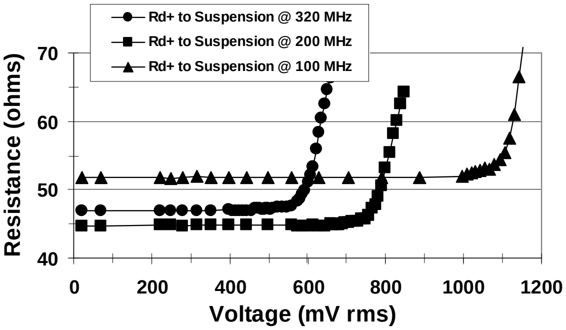

Fig. 6. GMR sensor resistance vs. input voltage for three different heads at three different frequencies.

Figure 6 shows the GMR sensor resistance vs. input voltage for three different heads with similar resistance at three different frequencies. For each head, the signal was connected between the reader input and suspension (Rd+ to suspension). Note that as the frequency decreases from 320 MHz to 100 MHz, the failure threshold increases. This is expected from the current vs. frequency behavior shown in Fig. 4, since current flow at frequencies lower and higher than resonance is reduced, requiring a higher voltage to reach the failure current through the GMR sensor.

Figure 7 shows the failure voltage vs. frequency for both input cases: Rd+ to Rd- and Rd+ to suspension.

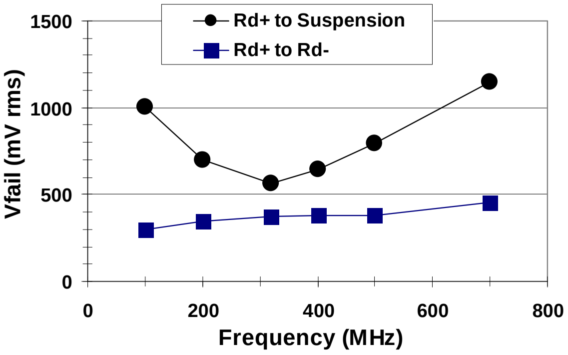

Fig. 7. Measured failure voltage vs. frequency for signal input across Rd+ to Rd- and Rd+ to suspension.

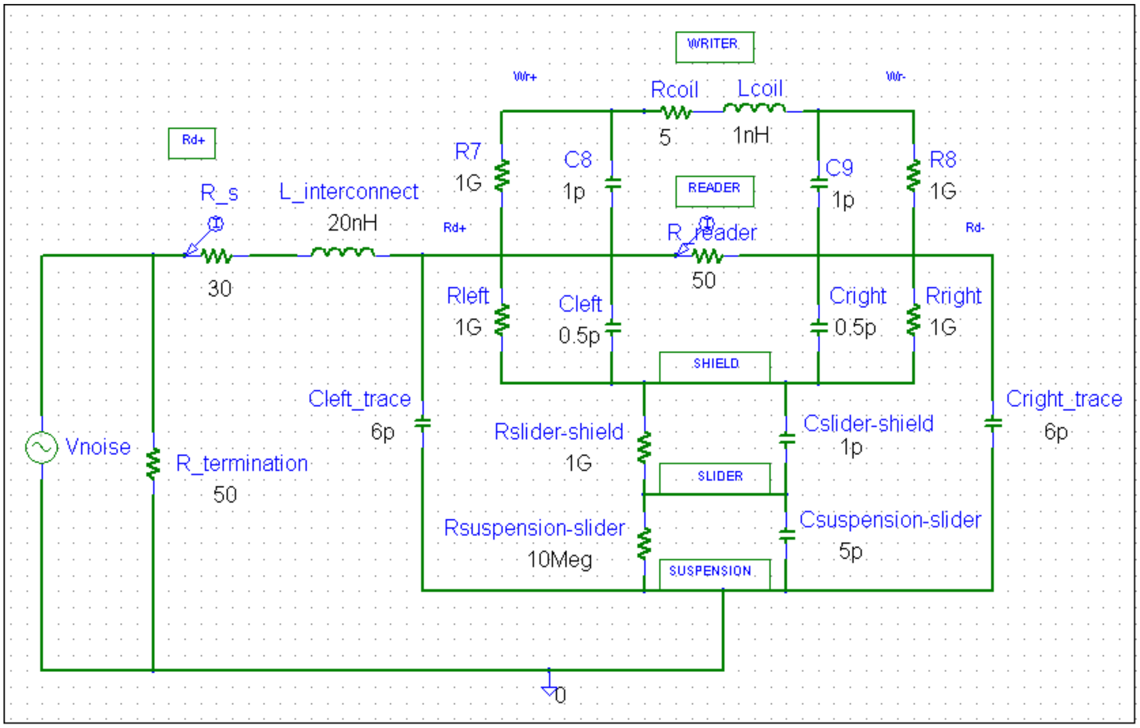

Fig. 8. Simplified lumped-element SPICE model for a recording head with the slider on a suspension. Noise signal source (Vnoise) is shown connected across Rd+ and suspension.

For the Rd+ to Rd- input case, the failure voltage is relatively flat from 100 MHz to 700 MHz. In contrast, the failure voltage for the Rd+ to suspension case depends strongly on frequency and has a minimum at 320 MHz. This behavior is consistent with the minimum in input impedance and higher current flow at resonance.

B. SPICE Modeling

It is always instructive to construct a lumped-element circuit for use in SPICE circuit simulations. Once the model is verified, SPICE simulations can help develop a deeper understanding by simulating other component values or signal sources that may be difficult to test experimentally.

Figure 8 shows a simplified lumped element SPICE model for a recording head with the slider on a suspension [3]. The voltage source is shown connected to the Rd+ and suspension, but the source was also connected across the reader inputs. While one normally concentrates on the DC resistances at low frequencies, it is the capacitive coupling which leads to current flow and failure at high frequencies. Therefore the DC resistances of Rleft, Rright, R7, R8, Rslider-shield and Rsuspension-slider actually have little or no effect on the high-frequency current flow.

Figure 9 compares the experimental and SPICE total current vs. frequency for a 130 mVrms signal connected across the Rd+ and suspension. The SPICE results are an excellent fit to the data. Initial values for the components were based on reasonable estimates. Then, the values for R_s, L_interconnect, Cleft_trace and Cright_trace were adjusted to match the experimental data.

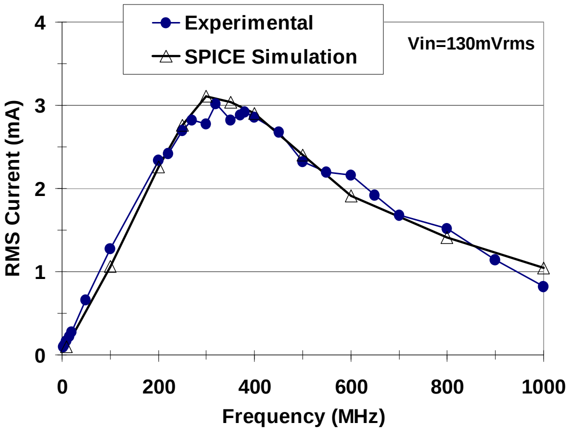

Fig. 9. Comparison of measured and SPICE simulated input current vs. frequency.

Using the measured failure current vs. frequency from Fig. 7, with the signal source connected across the Rd+ and Rd- inputs, in the SPICE model, the failure voltage vs. frequency for the signal source connected across Rd+ and suspension can be simulated. Fig 10 compares the measured failure voltage vs. frequency to the failure voltage calculated from the SPICE model. The failure level data from the SPICE model agrees extremely well with the measured failure voltage in the 100 to 700 MHz range. At 10 MHz, the SPICE model predicts a failure voltage of 11.3V.

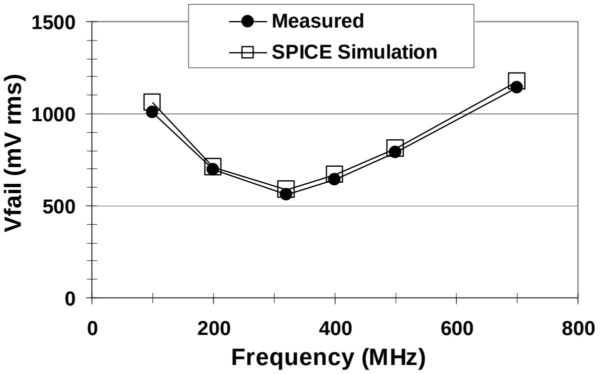

Fig. 10. Comparison of measured and SPICE simulated read sensor failure voltage vs. frequency. The signal connection was across a reader input and the suspension (Rd+ and suspension).

V. Discussion

One practical application of EOS testing is to set realistic voltage and current specifications in manufacturing operations that involve repetitive, high-frequency transients being applied across any pair of inputs to the device. These test results clearly show that, to prevent damage and resistance change to this head design, high frequency noise transients should be kept well below 300 mV across the GMR inputs and well below 500 mV across a reader input and the suspension. While the failure levels below and above the resonance are higher, a prudent approach would be to set the voltage or current specification based on the lowest failure voltage at resonance, since transient signals are likely to contain higher frequency harmonics.

As the head damage threshold decreases and the number of automated manufacturing processes with electrical and electronics equipment increases, the effect of electrical noise on chassis "ground" can be expected to become increasingly important to understand and control. In addition to traditional management of ground for ESD and safety, a new requirement is needed to manage electrical noise on grounds. Management of noise, or electromagnetic interference (EMI), can reduce defects in production. The greatest benefits of such EMI management will be realized if addressed in a methodical and concentrated effort, as has been done for ESD control.

VI. Summary and Conclusions

The low voltage, high frequency behavior of magnetic recording heads using a sinusoidal signal was investigated. When the signal was applied across the two reader inputs, the failure voltage from 200 kHz to 1 GHz was a constant 300 mV. But when the signal was applied across a reader input and the suspension, the failure voltage varied strongly with frequency, with a minimum of about 550 mV at 320 MHz. This behavior is explained by an RLC resonance at 320 MHz. At resonance, the failure voltage for high frequency voltage transients applied across the reader input and the suspension is surprisingly close to the failure level when the voltage is applied directly across both reader inputs.

It is concluded that characterization across all inputs of a device from DC to 1 GHz is useful in understanding failure thresholds due to high frequency noise transients.

References

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