A GENERATION MECHANISM OF ELECTROMAGNETIC NOISE ON THE CIRCUIT DUE TO GROUND POTENTIAL VARIATION

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Abstract: In this study, the noise voltage on the circuit installed in the frame caused by the ground potential variation and the influence of the resistance of the frame ground on the noise voltage on the circuit are discussed. It is concluded as a result of measurement and circuit simulation that the noise voltage gets lower as the grounding resistance becomes high and the capacitive coupling between the frame and the circuit dominates the noise on circuit.

Key words: grounding resistance, ground potential variation, electromagnetic noise, circuit simulation

1. Introduction

It is well known that the purpose of grounding is for protection and safety, and to establish the reference voltage for electric circuits. In the case that the ground potential (specially, frame ground potential) varies due to current caused by electromagnetic discharge and common grounding with other systems, the circuits placed in a frame sometimes upsets. Generally speaking, it is said that the circuit doesn't upset in the case that the power supply voltage and the signal voltage vary at the same amplitude and phase even if the circuit's reference voltage varies (that is, common mode voltage is given to the circuit).

However, in the practical situation, the circuits upset caused by ground potential variation occurs. Therefore, the technologies to suppress the potential variation by making grounding impedance small, giving the independent grounding to each system, and so on, are applied to keep away from circuits' upset. In the practical applications, the ground potential variation sometimes cannot be suppressed. And, any studies to guarantee stable circuit performance against the ground potential variation have not been reported. As a first step to realize stable circuit, it is demanded to find out what kinds of parameters affect circuits' upset. The authors clarified the relationship between the unbalance of circuit's wirings and the circuit's upset[1] and the relationship between the stray capacitance across primary and secondary windings of step-down transformer used in the stabilized DC power supply and the circuit's upset[2].

In this study, the noise voltage on the circuit installed in the electric equipment chassis (frame) caused by the ground potential variation and the influence of the grounding resistance between circuit's ground and frame ground on the noise voltage on the circuit are discussed based on the experiments and simulations. It is concluded that the noise voltage gets lower as the grounding resistance becomes high and the capacitive coupling between the frame and the circuit dominates the noise on circuit.

2. Experimental Apparatus

Figure 1 shows the experimental apparatus. The aluminum plate whose size is 600mm x 1000mm is used as the ground plate. And, the aluminum plate whose size is 320mm x 250mm is used as the electric equipment frame in order to make experiment and simulation simple. The simple test circuit shown in Fig.1 composed of two resisters is also used in order to make experiment and simulation simple. The size of test circuit's loop is 290mm x 50mm.

In this experiment, the noise voltage generated across the resisters at the test circuit is measured by the digital sampling oscilloscope (LeCroy, model 9354AL) when impulse noise voltage whose amplitude is 200V and pulse width is

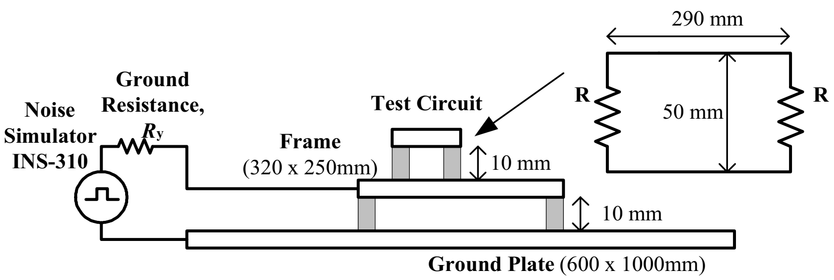


Fig. 1 Experimental Apparatus.

1μS, generated by the impulse noise simulator (Noise Laboratory, INS-310), is injected between the frame and the ground plate through grounding resistance $\boldsymbol{R}_y$.

3. Experimental Results

In this experiment, the noise voltages generated across the resisters in the test circuit put on the frame are measured in the case that the grounding resistance, $\boldsymbol{R}_y$ is 0Ω, 10Ω, 100Ω, 1kΩ and 10kΩ and the circuit's resistances, $\boldsymbol{R}$ is 10Ω, 100Ω, 1kΩ, 10kÙ, 100kΩ and 1MΩ, respectively.

Figs. 2 and 3 (a)-(d) show the typical waveforms of measured noise in the case that $\boldsymbol{R}_y$ is 0Ω and 10kΩ, respectively. And Fig.4 shows the ratio, G of peak voltage, V_{peak} of noise observed on the test circuit with the noise voltage, V_{noise} applied by the noise simulator, as shown in Eq. (1).

$$\boldsymbol{G} = \mathbf{20}\ \mathbf{log_{10}}\ |\ \boldsymbol{V}_{\mathbf{peak}}\ /\ \boldsymbol{V}_{\mathbf{noise}}\ | \qquad (1)$$

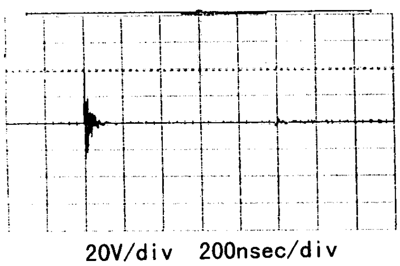
4. Simulation Results

In order to confirm the above measured results, the circuit simulation by a circuit simulator SPICE is carried out. Fig. 5 shows the circuit diagram used in this circuit simulation. In the simulation circuit shown in Fig. 5, **R** and $\mathbf{R}_y$ are the same as them shown in Fig. 1. **C1** is the stray capacitance between the ground plate and the frame, **C2** is the stray capacitance between the test circuit loop and the frame, **C3** is the probe capacitance of the oscilloscope and is equal to 6.5pF, and **L1** is the inductance of test circuit loop wire. The values of **C1**, **C2** and **L1** are decided to be 100pF, 20pF and 0.1μF, respectively, due to the measured result by the impedance analyzer (Agilent Technology, model HP4195A). The circuit simulation is carried out on the same condition as the above experiment.

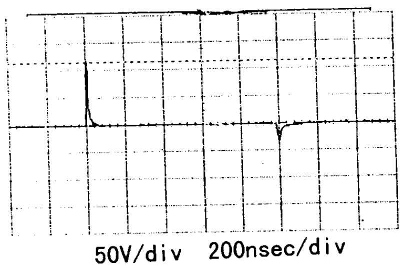
Figs. 6 and 7 (a)-(d) show the circuit simulation results in the case that the grounding resistance, $\boldsymbol{R}_y$ is 1Ω and 10kΩ, respectively. Lines on Fig.4 show the voltage ratio, G shown in Eq. (1).

5. The Comparison of the Simulation Results with the Measured Results

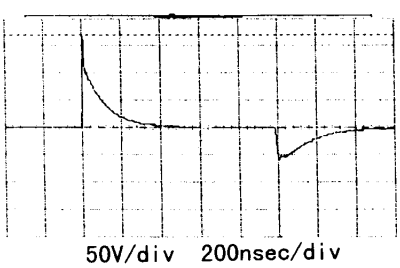
In comparison of the simulation results shown in Figs. 6 and 7 (a)-(d) with the measured results shown in Fig. 2 and 3 (a)-(d), it is shown that voltage is slightly different but these shapes of the waveforms are roughly similar. In Fig. 4, the simulation results have similar tendency with the measured results. The difference between the simulation results and the measured result is slightly large in the case that the circuit resistance or the grounding resistance is small. This difference may be caused by parasitic resistances that wires and probes have, and the neglection of inductive coupling. And the measured noise voltage saturates less than -50dB. The value of -50dB is corresponding with 500mV. This value is the measurement limit of experimental apparatus.



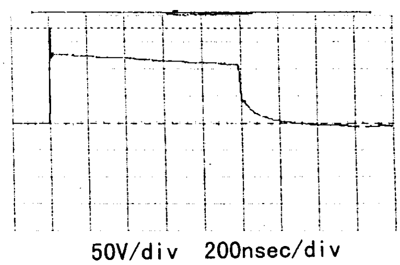
(a) Circuit Resistance : 10 Ω



(b) Circuit Resistance : 1k Ω

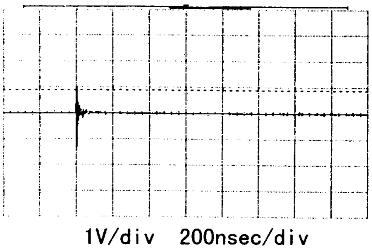


(c) Circuit Resistance : 10k Ω

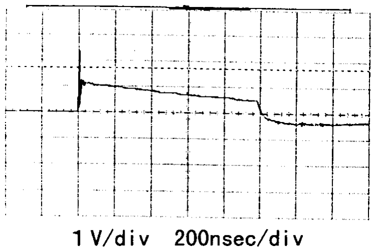


(d) Circuit Resistance : 1MΩ

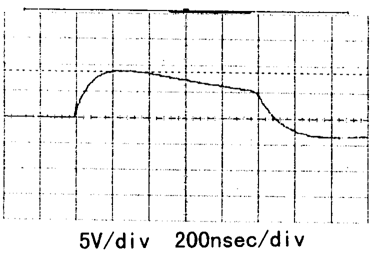
Fig. 2 Noise Waveforms Measured on the Test Circuit (Grounding Resistance, Ry : 0Ω)



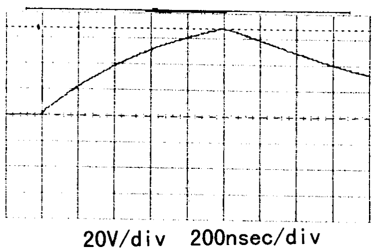
(a) Circuit Resistance : 10 Ω



(b) Circuit Resistance : 1k Ω



(c) Circuit Resistance : 10k Ω



(d) Circuit Resistance : 1MΩ

Fig. 3 Noise Waveforms Measured on the Test Circuit (Grounding Resistance, Ry : 10kΩ)

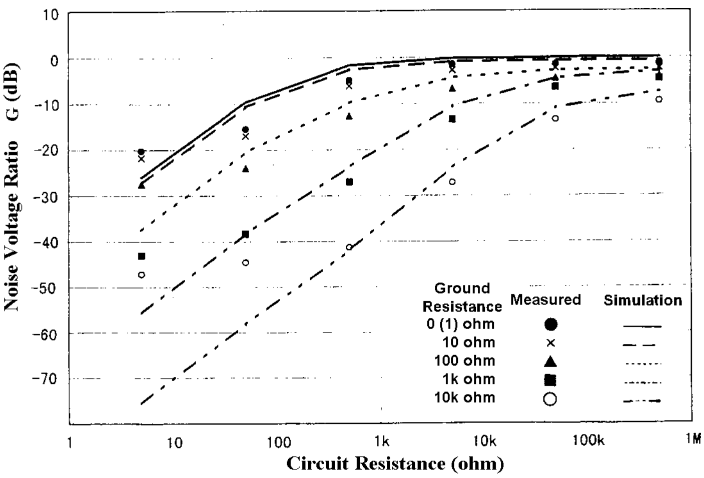
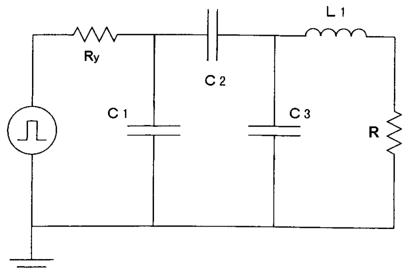


Fig. 4 The Relationship between the noise voltage and Grounding/Circuit Resistance.



R : Resistance on the test circuit loop.
Ry : Grounding resistance.
C1 : Stray capacitance between the ground plate and the frame.
C2 : Stray capacitance between the test circuit loop and the frame.
C3 : Capacitance of oscilloscope probe.
L1 : Inductance of the test circuit loop wire.

Fig. 5 Circuit Diagram for the Simulation.

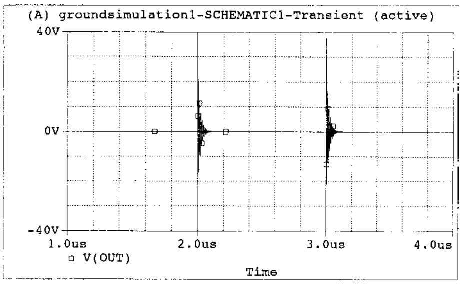
5. Conclusions and Future Issues

In this study, the influence of the grounding resistance on the noise generated on the circuit caused by the ground potential variation is clarified. As shown in the above mentioned measurements and simulations, the followings are concluded.

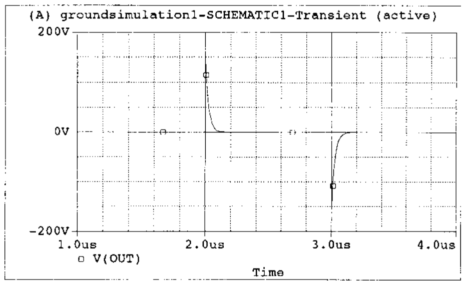
- The noise voltage generated on the circuit caused by the ground potential variation gets lower as the grounding resistance becomes high.
- The noise voltage generated on the circuit caused by the ground potential variation gets lower as the circuit resistance becomes high.
- The capacitive coupling between the frame and the circuit dominates the noise on circuit.

The above results are useful to realize the stable circuit.

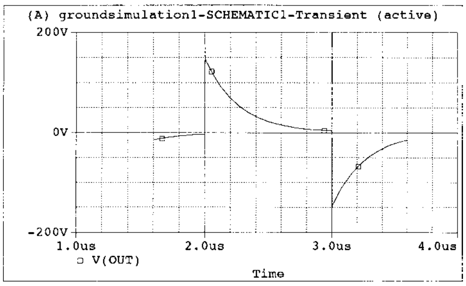
The future issue is to enhance the simulation accuracy.



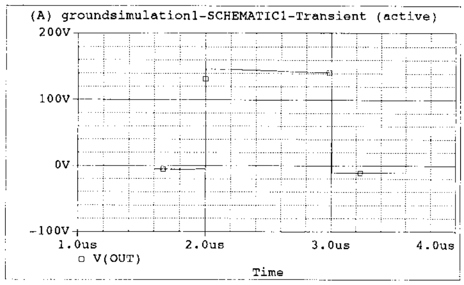
(a) Circuit Resistance : 10 Ω



(b) Circuit Resistance : 1k Ω

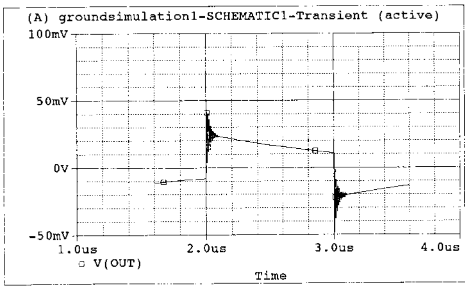


(c) Circuit Resistance : 10k Ω

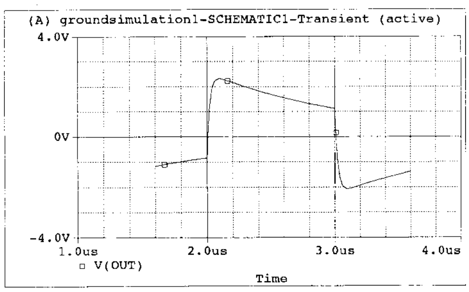


(d) Circuit Resistance : 1MΩ

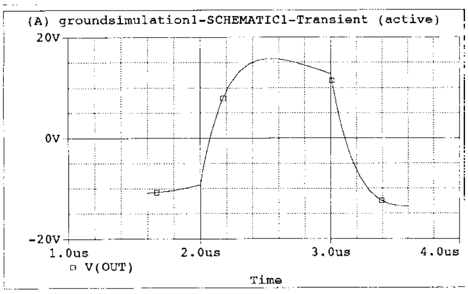
Fig. 6 Simulation Results of Noise Waveforms (Grounding Resistance, Ry : 1Ω)



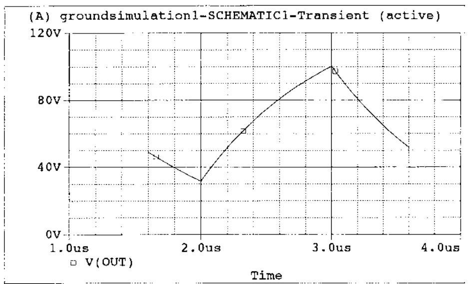
(a) Circuit Resistance : 10 Ω



(b) Circuit Resistance : 1k Ω



(c) Circuit Resistance : 10k Ω



(d) Circuit Resistance : 1MΩ

Fig. 7 Simulation Results of Noise Waveforms (Grounding Resistance, Ry : 10kΩ)

References

[1] S. Nitta, K. Ebihara, A. Mutoh and H. Kakimoto, "The Malfunction Mechanism of Digital Circuit due to Ground Potential Fluctuations (Part II)," Proc. of the 1991 IEEE Int'l Symp. on EMC, Cherry Hill, NJ, Aug. 1991, pp.405-406.

[2] S. Nitta, K. Ebihara and E. Takechi, "The Malfunction of Digital Circuits Caused by Variation of Ground Potential (Part I)," Proc. of the Int'l Symp. on EMC, Nagoya, Japan, Sep. 1989. pp.394-399