PREFERRED
RELIABILITY
PRACTICES

# ELECTROMAGNETIC INTERFERENCE ANALYSIS OF CIRCUIT TRANSIENTS

**Practice:**

Network circuit analysis programs are valuable tools in the analysis of switching circuit transients which are capable of generating conducted and radiated electromagnetic interference (EMI). The analysis is performed to insure that disruptions or degradations due to EMI do not occur. EMI is capable of disrupting the normal operating environment of an electronic circuit or degrading the performance of such a circuit.

**Benefits:**

Circuit analysis for the purpose of evaluating the conducted and radiated EMI from a switching circuit has resulted in the proper design of switching circuit electronics. The devices connected to electronic switching circuits will not be adversely affected by transient currents and associated radiated fields generated by such currents.

**Programs That Certified Usage:**

LPX - Liquid Plume Experiment (SDIO), Centaur Battery Thermostats Design

**Center to Contact for Information:**

Jet Propulsion Laboratory (JPL).

**Implementation Method:**

Transient circuits are found on many types of analog electronic devices, e.g., thermostats and relays, where the current needs to be switched "ON" and "OFF" at required intervals. Transient currents in these devices can generate a significant amount of conducted EMI. The magnitude of conducted EMI can be expressed in dB$\mu$A[1] vs frequency after a Fourier Transform from the time domain to the frequency domain. Furthermore, the transient current, when it flows through a wire or conducting line, can make the conductor behave as a radiating antenna. The fields generated by such an antenna (normally expressed in dB$\mu$V/m [2] vs frequency) can couple to nearby electronic devices, hence degrading their performance. The EMI analysis of switching transients can be divided into three tasks.

1. As noted in the referenced paper, SPICE (Simulator Program with Integrated Circuit Emphasis), one of the most widely used modeling tools for circuit analysis, can be adapted to this type of problem. The switching circuit and all the electronic devices connected to it directly are modeled



[1] decibels relative to 1.0 microampere

[2] decibels relative to 1 microvolt per meter

# ELECTROMAGNETIC INTERFERENCE ANALYSIS OF CIRCUIT TRANSIENTS

using the SPICE code. In this process it is important to realize that the switching parameters (e.g. "ON/OFF" time, $R_{ON}$ & $R_{OFF}$ resistances) must be modeled as accurately as possible. The objective in SPICE modeling is to obtain the "magnitude vs time" profile of the transient current at a location of interest (e.g. across an L, or R, or C component) which would be indicative of the propagation path followed by the transient current that would affect directly other electronic circuits.

2. Once the transient current time-domain profile is known, the Fourier Transform can be calculated. The Fourier Transform is indicative of the magnitude of conducted EMI, at a particular location, as a function of frequency (most conducted emissions are usually in the frequency range of KHz through MHZ). The magnitude of conducted EMI can then be compared with pre-established maximum allowed levels of conducted noise to assess the magnitude of exposure by a susceptible device.

3. If the transient current can be calculated at a location on a conductive line (e.g. wire, cable), it is possible to estimate the amount of radiated EMI emitted by the conducting line as it temporarily behaves as an antenna. From the Fourier Transform previously calculated, the "magnitude" vs "frequency" component terms are used as driving current sources for the antenna(s) under consideration. A Method of Moments (Ref. 1) code is then used to model the conducting line as a wire antenna and calculate the magnitude of the electric fields as a function of frequency.

Figure 1 shows an example of a heater circuit for a battery. The heater circuit consists of two "ON/OFF" switching thermostats connected to the heater filament (load) inside the battery. Figure 2 shows a SPICE model of the heater circuits. The transient current due to "ON/OFF" switching can be calculated across several of the parameters illustrated in Figure 2. However, since the battery which supplies the thermostats' current also feeds other electronic devices, it is important to evaluate the conducted noise across the battery ($V_1$ in Figure 2). The conducted and radiated emission can be evaluated by following steps 2 and 3 above.

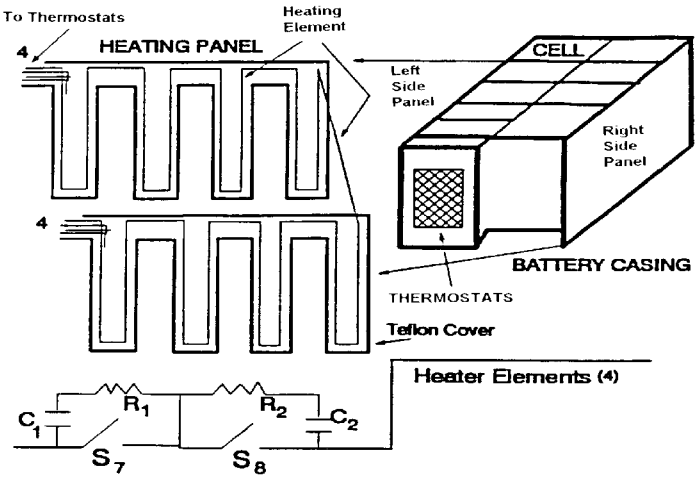


**Figure 1. Battery Thermostats & Heating Elements**

# ELECTROMAGNETIC INTERFERENCE ANALYSIS OF CIRCUIT TRANSIENTS

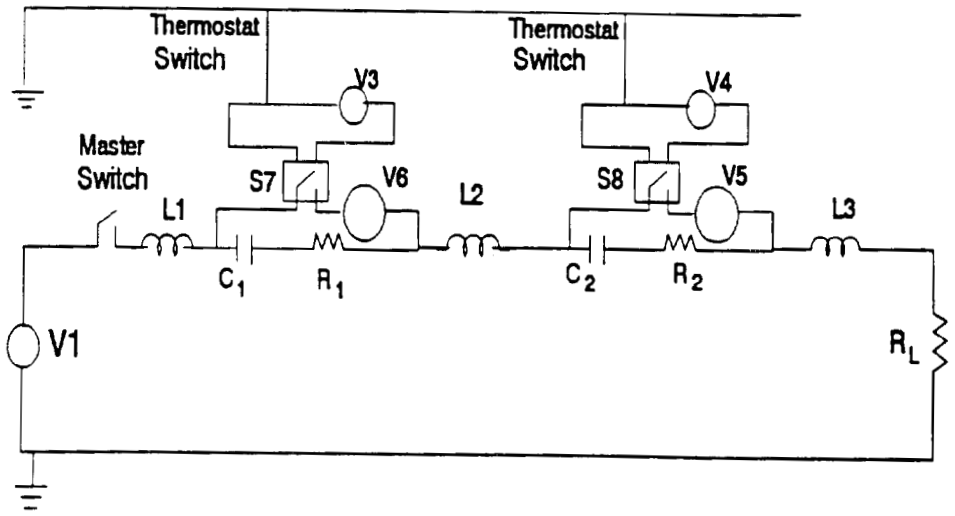


**Figure 2. SPICE Thermostats Switching Modeling**

**Technical Rationale:**

It is important to assess the amount of conducted and radiated EMI being emitted from transient circuits to determine if changes are needed to suppress the EMI.

**Impact of Non-practice:**

The neglect of EMI noise from transient circuits can cause interference problems and/or degraded performance in electronic devices.

**Related Practices:**

1. *Analysis of Radiated EMI From ESD Events Caused By Space Charging*, Practice No. PD-AP-1309

**References:**

1. IEEE International Symposium on EMC, 1988; "A Simple SPICE Model for Coupled Transmission Lines", Clayton R. Paul