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EMC investigations in Switch Mode Power Supply

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OURE REPORT

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Abstract

An experimental investigation on the radiated emissions caused by a high current switched mode power supply (SMPS) that supplies a CPU was performed. The emissions testing revealed data that could be used to predict causes of electromagnetic radiation from inside the computer. The noise sources identified included clocks on the motherboard, which was excluded for the purposes of this study. Testing concentrated on the SMPS and some theoretical ideas are proposed for better construction of the power supply.

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Background Information

There are requirements imposed by government agencies like the FCC in order to control the Electromagnetic interference produced by products. These FCC rules are contained in Title 47 of the code of Federal Regulations, of which Part 15 is of specific importance for the radio-frequencies devices. Some examples of these devices are digital computers whose clock signals generate radiated emissions in the 100 KHz- 30 GHz band.

Traditionally, the emissions have been dominated by clocks and digital signals. As a consequence of the reduced core voltages (approaching 1V) the VCC currents of the CPUs are approaching > 100 A. The currents are provided by a local step-down DC-DC converter. Driven by other design requirements, these DC-DC converters now produce significant emissions up to 1 GHz and start to be the main emissions source.

Test Setup

The testing was performed at the UMR EMC lab's semi-anechoic chamber. This chamber eliminates high outside ambient noise, and reduces the time needed to distinguish ambient noise from EUT emissions. The setup (Figure 1) included a Biconolog antenna which was capable of measuring between 30MHz – 5GHz. The signals were measured using a spectrum analyzer (Rohde and Schwarz FBEB series).

A PC having the SMPS and motherboard were taken for testing. In the first test the entire PC was run with 110V power and the radiated emissions from the PC was analyzed. This was to verify that the PC had in fact passed the FCC class B regulations and CISPR 22 B limits for Electromagnetic compatibility when it was sold.

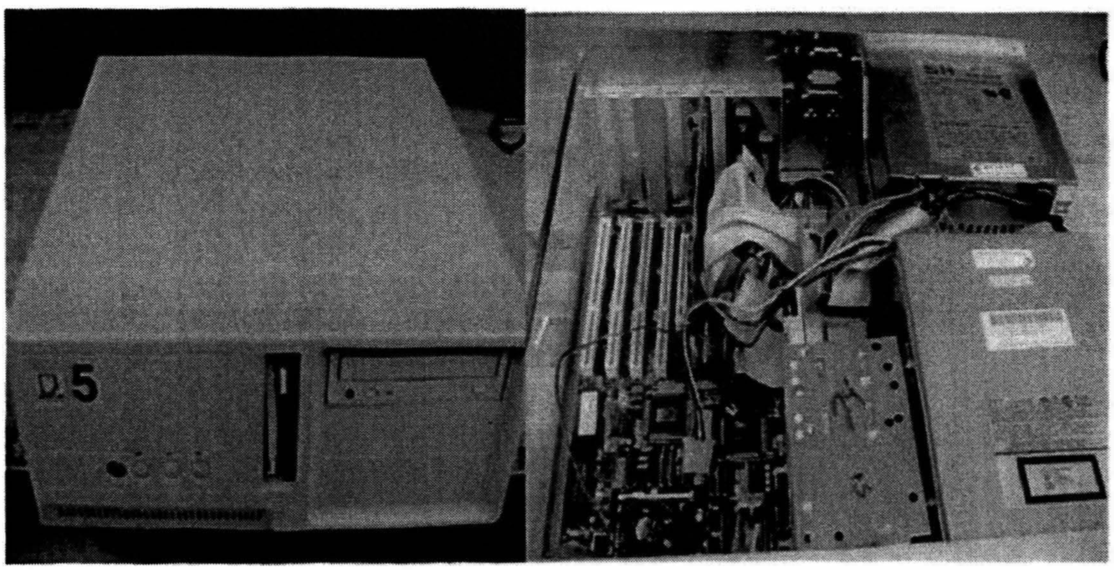


Figure 1: On the left, the computer under test. And on the right, case is opened.

Testing and Results

This initial testing was done to identify all the types of noises being emitted from a PC when the cover is opened. This testing would allow us to identify frequencies from the clocks which we are not interested in for this research. It would also allow us to identify the noise sources from the SMPS unit.

The test setup and the results are given below:

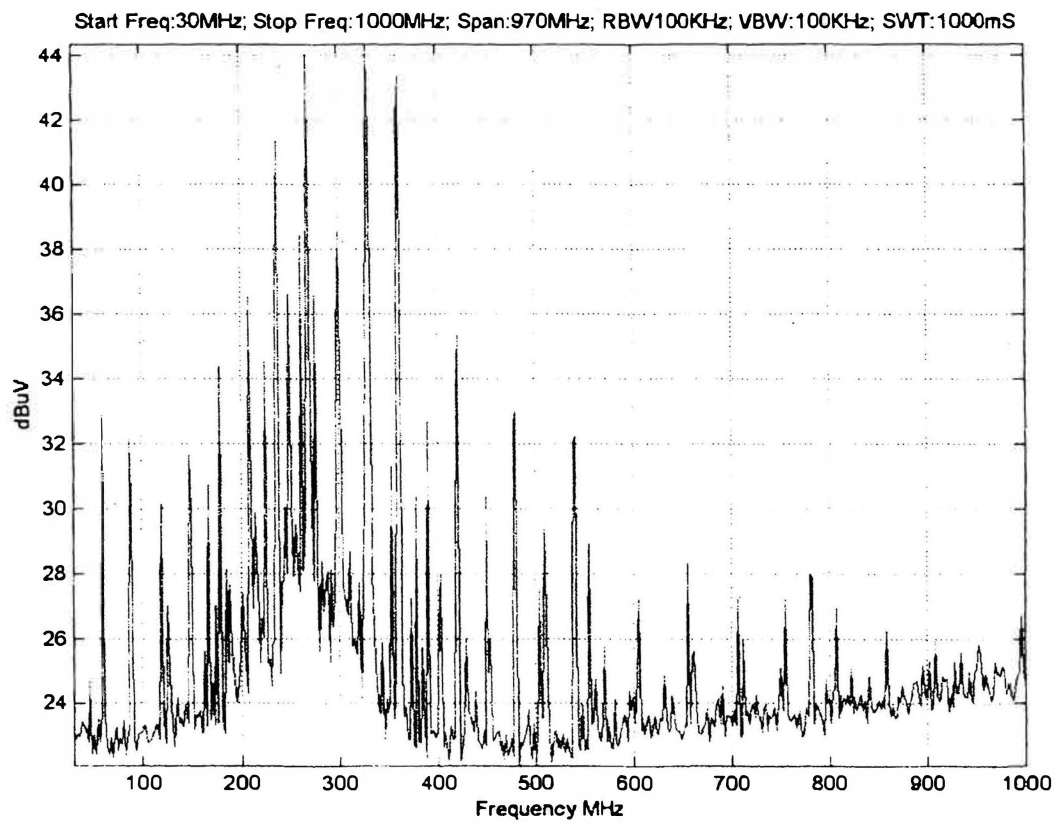


Figure 2: 30-1000 MHz Noise Spectrum.

From the figure above it is clearly evident that there is a 60 MHz and a 100 MHz clock inside the PC. We also observed some broadband noises around 330 MHz. We investigate further by turning everything off on the PC except the fan. This was done to make sure that the SMPS is being utilized by some component inside the PC.

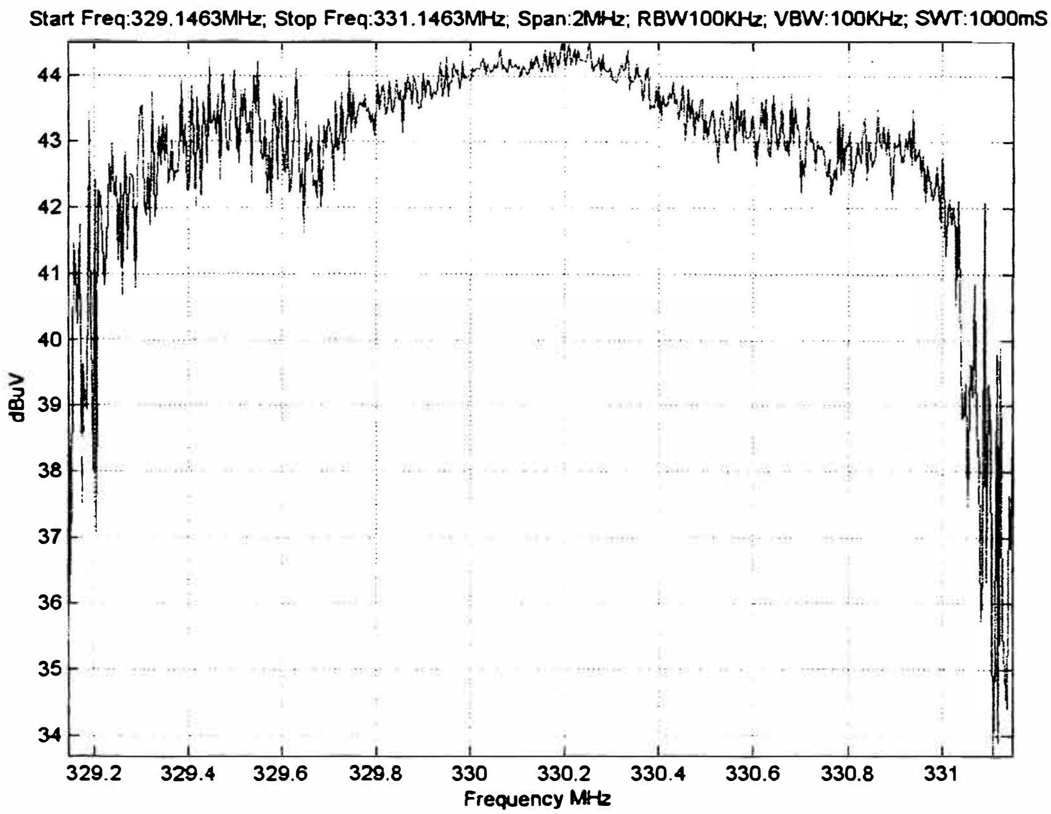
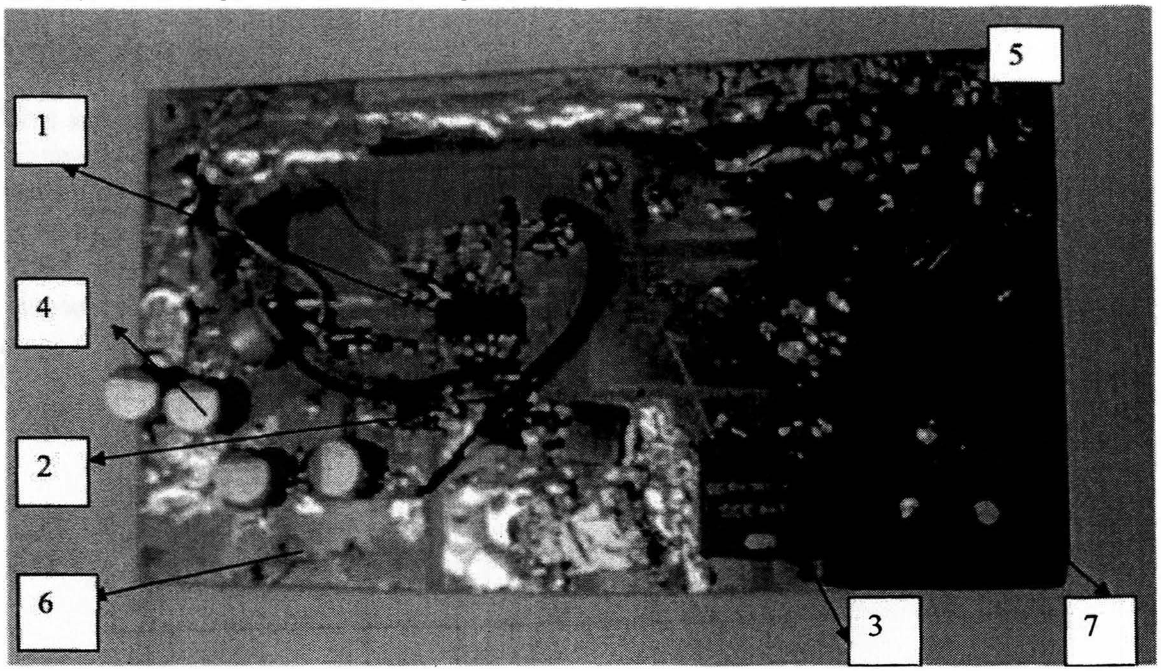


Figure 3:330 MHz broadband signal.

The above signal is observed around 330MHz and it confirms that the power supply is the cause of this broadband noise. A theoretical investigation of the main power supply was done.

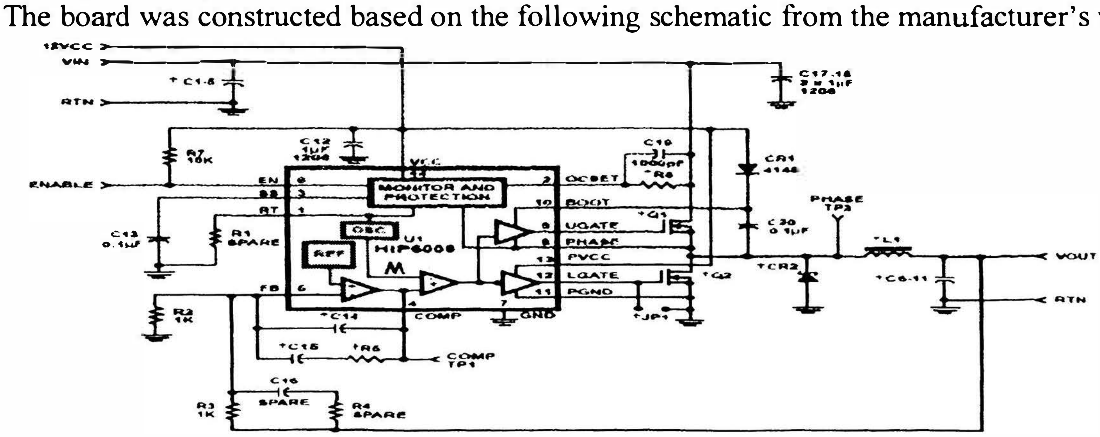
CONSTRUCTION OF DC-DC CONVERTER



In this step a DC-DC converter board was constructed with Mr. Zhe Li's help. The board has the following components (labeled in the figure):

1. HIP6006 – N-channel MOSFET driver for a synchronous-rectified buck topology for microprocessor applications.
2. IRF7821 – Power MOSFET for high-frequency point-of-load synchronous buck converter application.
3. Inductor
4. Decoupling Capacitors – To reduce the noise level
5. Resistive load – To check the working of the DC-DC converter
6. Input voltage – 5V
7. Output Voltage

The board was constructed based on the following schematic from the manufacturer's website.



In the above circuit we modified our DC-DC converter to have a 200 KHz operating frequency for the HIP6006 (This is the default speed of the driver). The HIP6006 has options to increase this operating frequency by adding a resistor and capacitor at pin number 1. The output voltage can be adjusted in such a way that it is less than the input voltage or almost close to input voltage.

Due to some technical difficulties we were unable to check if this circuit was working right. We intended to do some near-field and far-field emissions testing, but since the circuit wasn't working and time constraints this will be considered at a future date.

Theoretical Investigations

A. Construction of the SMPS chassis:

Generally a SMPS has two main components. One component converts the AC to DC and is usually connected to the loads on the PC using cables. The output from this converter will have current flowing to the loads on these cables. These cables start acting as an antenna and are main sources of EMI noise. The second component is the control circuit section. The control circuit shouldn't be placed near the cables to reduce the electromagnetic coupling between them.

The case in which this whole circuit is placed inside is usually made of steel. Steel is effective shielding material of EMI noise. However during construction it has to be made sure that the case is water-tight i.e., it has to come together into one piece such that it won't let any water leak. Water is being used as an analogy to the EMI noise. Some effective ways to make sure that the shielding better are by using gaskets or by EMI fingers.

B. EMI considerations for Design and Topology

For economic purposes EMI has to be considered in the early stages of EMI design.The SMPS produces high-frequency noises as a result of its operations. In some parts of the circuit the di/dt and dv/dt is high and this results in a lot of EMI being caused by the SMPS. The saw-toothed shaped waveform is produced by the switching inverter which is what causes the high dv/dt. The current SMPS are using transistors with very fast rise times and fall times. They are approximately in 100 nano seconds range.

Therefore it is very essential to mount these transistors to minimize the area of radiating elements. There are also some parasitic components which influence the EMI of a power transistor.

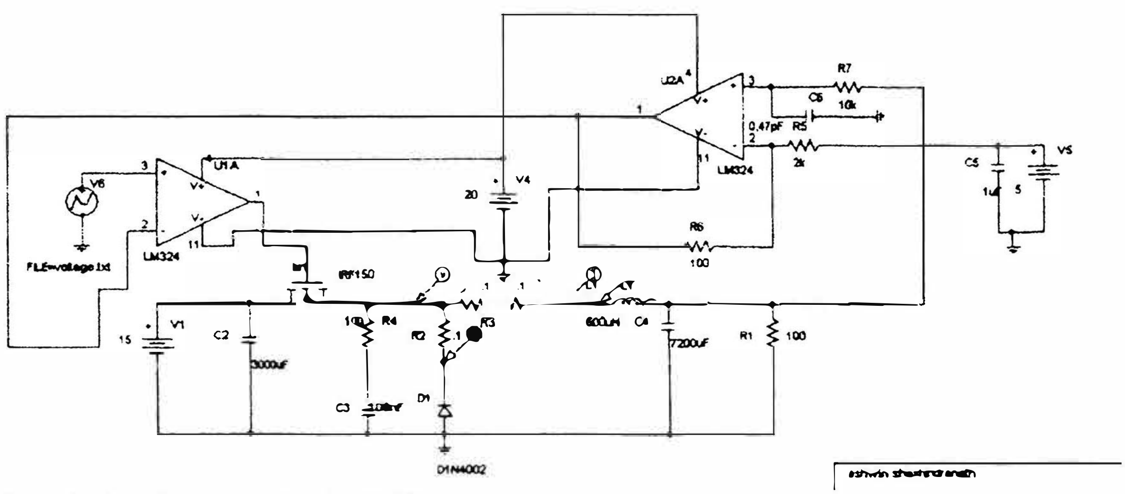
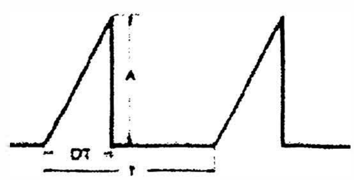


Figure 4: Buck-Booster design for SMPS.

Above is a possible theoretical Buck-Booster design that could be implemented to make a DC-DC converter for the SMPS.
Semiconductors like the MOSFET in the above circuit are strong sources for Differential-mode EMI. Good layout design will reduce the Differential-mode EMI. Good designs should make sure that the wires carrying a switching waveform (such as the saw-toothed shaped waveform) should be as close to each other as possible. RC snubbers can be used to reduce the ringing effect caused the L-C circuit. Good component selection will also reduce Differential-Mode EMI.

Clipped sawtooth wave



$$C_{n,rms} = \frac{A\sqrt{2D}}{(2\pi nD)^2}\sqrt{2(1-\cos 2\pi nD)+2\pi nD(2\pi nD-2\sin 2\pi nD)}$$

Figure 5: Clipped saw-toothed waveform of input current.

In figure 6 a method to dampen the effects of the fast risetime/fall times is shown.

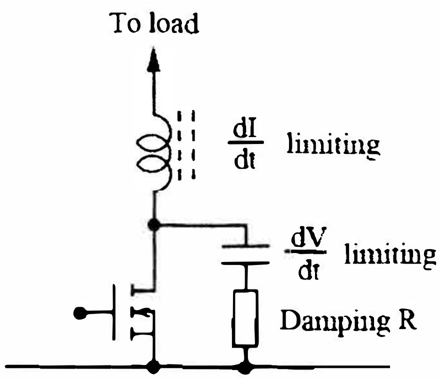


Figure 6: Adding L, C, R to slow the rising and falling edges of the current and voltage waveform.

Common Mode EMI:

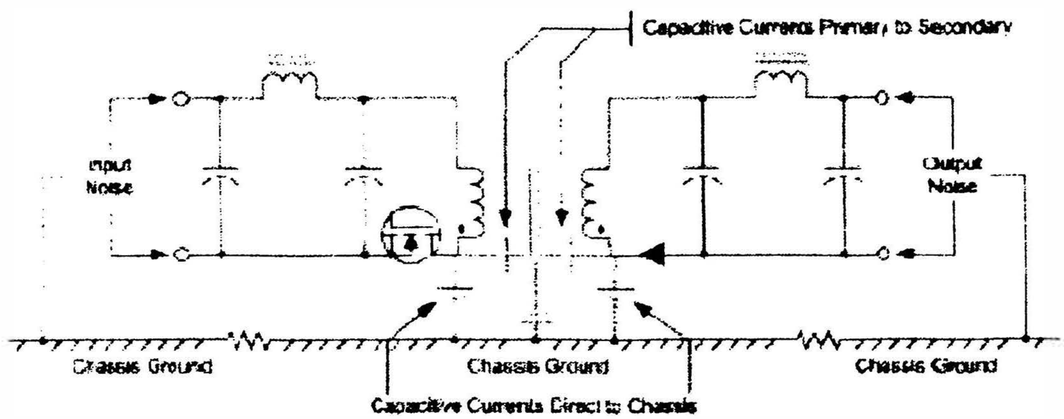


Figure 7: Capacitive current (i.e., currents associated with parasitics are shown).

The main reasons for common-mode EMI are the parasitic capacitances in the power transistor in the SMPS design. The parasitics which cause EMI are the collector to base and collector to heat sink capacitances. This can be minimized by reducing the stray capacitances between the circuit and the ground. It can also be reduced by proper component selection while building the circuit.

EMI Line Filter:
A good EMI line filter can be used to attenuate both common-mode and Differential-mode noises. Differential-mode noises can also be decreased by using X-capacitors and Common-mode noises can be decreased by using Y-capacitors.

Grounding
Ground plane should be as low resistance as possible. Single point grounding will help reduce the EMI.

Conclusion

Switch mode power supplies are notorious for creating Radio Frequency Interference and electromagnetic noise. The DC-DC converter that we constructed for microprocessor application didn't work as we expected. We hope to be able to work with in the future and make a good DC-DC converter with all the theoretical considerations taken intoaccount.

Low pass filters in the mains leads are vital to reduce conducted interference. Faraday screens between the transformer windings and around sensitive components, together with correct field canceling layouts on the circuit board, are also required to reduce electromagnetic noise and interference. The problems of smoothing of saw tooth current waveforms put a strain on capacitor design. The series inductance and resistance of standard electrolytic capacitors has a large effect on residual ripple and noise voltages at the outputs

Acknowledgements

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