White Paper # 5203

Voltage Regulators
They Ain't What They Used To Be

Introduction

Since the advent of electronic systems, electrical power related disturbances have had the ability to destroy components, disrupt system operation and interfere with productivity. Almost everyone has experienced the affects of power problems at one time or another, and it's a common belief that system failure is due to voltage "sags" and "surges". However, electronic technology is continuously evolving, and it is important to recognize that this evolution has changed the way systems respond to power disturbances. Voltage sags and surges are not the demons they once were, and voltage regulators no longer provide much protection for many modern systems.

The Evolution

When John Atanasoff and Clifford Berry invented the first working digital computer in 1939 at what is now Iowa State University, they built a machine that relied on vacuum tubes for the fundamental logic circuitry. These were high voltage, low current devices that were powered by basic "linear" power supply technology. From the ENIAC, EDVAC, and UNIVAC systems that followed to the more familiar systems of the mid-1980's, little change took place in power supply design.

By the late '80's, however, engineers had begun using large numbers of integrated circuits which themselves were being built with increasing numbers of transistor junctions. The result was a "low voltage" computer, which used substantial amounts of current. Linear power supply technology of the time was inefficient and a supply capable of meeting the current delivery requirements of the computer circuitry would be significantly larger than its predecessors. Designers were striving to miniaturize electronic systems and, larger power supplies were not consistent with this goal.

The result was the introduction of the switch mode power supply. This design eliminated the 60 Hz. stepdown transformer and series regulator section in favor of a pulse width modulated, high frequency circuit capable of rectifying line voltages down to usable, well regulated dc power for the computer's logic circuitry.

Fundamental Differences

This technological change is responsible for some fundamental differences in the way systems respond to power problems.

The linear power supply rectified incoming line voltage and supplied power to the logic circuitry through a series regulator. The range of this regulator was limited, however, and an input voltage that was too high or too low would quickly result in problems. Low input voltage would cause the supply output to "foldback" or drop below the operating tolerance of the logic circuit. Input voltage that was too high would activate the power supply's "crowbar" circuit. In the process of protecting itself, the power supply output would again fall below the operating tolerance of the computer's electronic circuitry.

Because line voltage variations are frequent, sags and surges were commonly the culprit in early electronic system failure. Dedicated electrical circuits were the first line of defense against this condition, and if ineffective, a voltage regulator was normally specified.

Switch mode supplies, however, are very different. The series regulator has been eliminated along with the input stepdown transformer. Switch mode power supplies consume current from the AC power supply for only portions of each power line cycle. Figure 1 illustrates the current demand waveform of a 200 watt switch mode supply superimposed on the voltage sinewave.

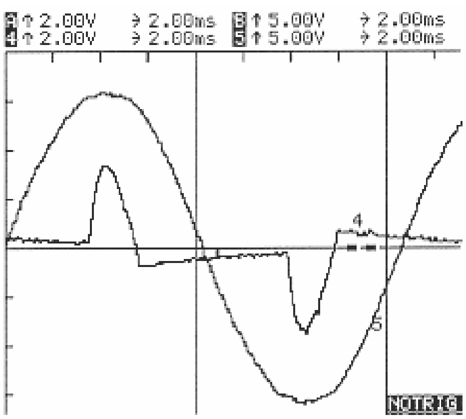

Figure 1

Not only are switch mode supplies considerably smaller and more efficient, but they are largely immune to voltage sags and surges. An explanation is found in the way the system operates.

Duty Cycle Is Everything

Because the switch mode supply draws current for only a brief time period, much can occur to the line voltage during the time the switcher is "turned off" with little effect on its operation. If line voltage sags or surges during the time the supply is "turned on," the supply compensates for the variation by adjusting its duty cycle or the time period over which it operates.

Figure 2 illustrates the current waveform of the same 200 watt switch mode supply operating from a line voltage of 75 volts.

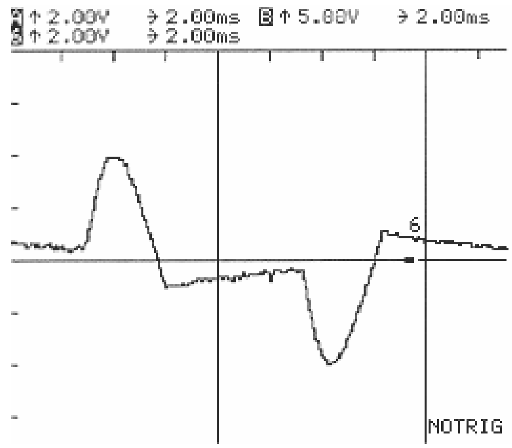

Figure 2

Note that the current waveform has become wider. In other words, with less peak current available, the supply is compensating by drawing current for a longer period of time. In this illustration, the power supply's voltage outputs were still supplying well regulated +5 and $\pm$12 volts under full rated load.

Built In Voltage Regulation

The capabilities of switch mode power supplies with regard to voltage regulation problems are well documented. In fact, it is the inherent tolerance to such voltage variations that makes it possible to operate a modern system from a standby UPS in which the computer may operate completely without power for as much as 5 or 6 milliseconds while it is transferred to a battery powered inverter.

Switch mode power supplies can be said to contain their own "built in" regulation capability. It is important to note that most voltage regulators can only adequately regulate down to 75% of nominal line voltage (90 volts in the case of a nominal 120 volt line). Switch mode power supplies are naturally tolerant of voltages well below the regulation capabilities of most regulators.

Compatibility Issues Abound

The most popular types of regulators are tap switching autoformers and/or transformers and ferroresonant transformers. Regardless of the type, these regulators all accomplish their function by controlling the current flowing in an electrical circuit.

This may have implications for the appropriate operation of switch mode supplies. From Figure 1, it is obvious that switch mode supplies gobble large amounts of current in a short period of time. Voltage regulators tend to be high impedance sources, which restrict the amount of current available to the supply at any given time. Under these circumstances, the switch mode supply can be "starved" for current and in the process cause significant voltage distortion on the output of the regulator. Figure 3 illustrates this condition.

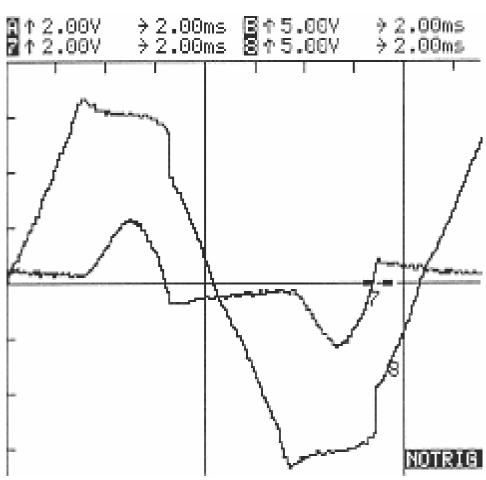

Figure 3

Significant noise generation may result, and there is conjecture in the industry about the stress placed on the supply by permanently altering its duty cycle.

All these are compatibility issues of the first order. Voltage regulation is no longer necessary for switch mode technology, although, it may still be required for systems with linear style power supplies. Eliminating the misapplication of voltage regulation technology will eliminate any concern for compatibility, too.

Appropriate Solutions

In the migration from linear supply to switcher, the input stepdown transformer was eliminated. In the process, the system's natural immunity to common mode noise and high voltage impulses was totally lost. Today's power protection solutions recognize that these immunities must be restored.

An appropriate solution for modern systems incorporates a surge diverter, an isolation transformer, and a noise filter. These three elements work in concert with the natural voltage regulating ability of the switch mode supply to provide all the power protection elements necessary for modern systems.

Conclusion

Voltage regulators no longer provide any needed protection for most modern computer systems. Solutions that include isolation transformers, surge diverters and noise filters are far more effective and do not introduce the compatibility issues that can create more power problems than are solved.