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Earth: Killer of Micro-Electronics



Mysterious energy pulses

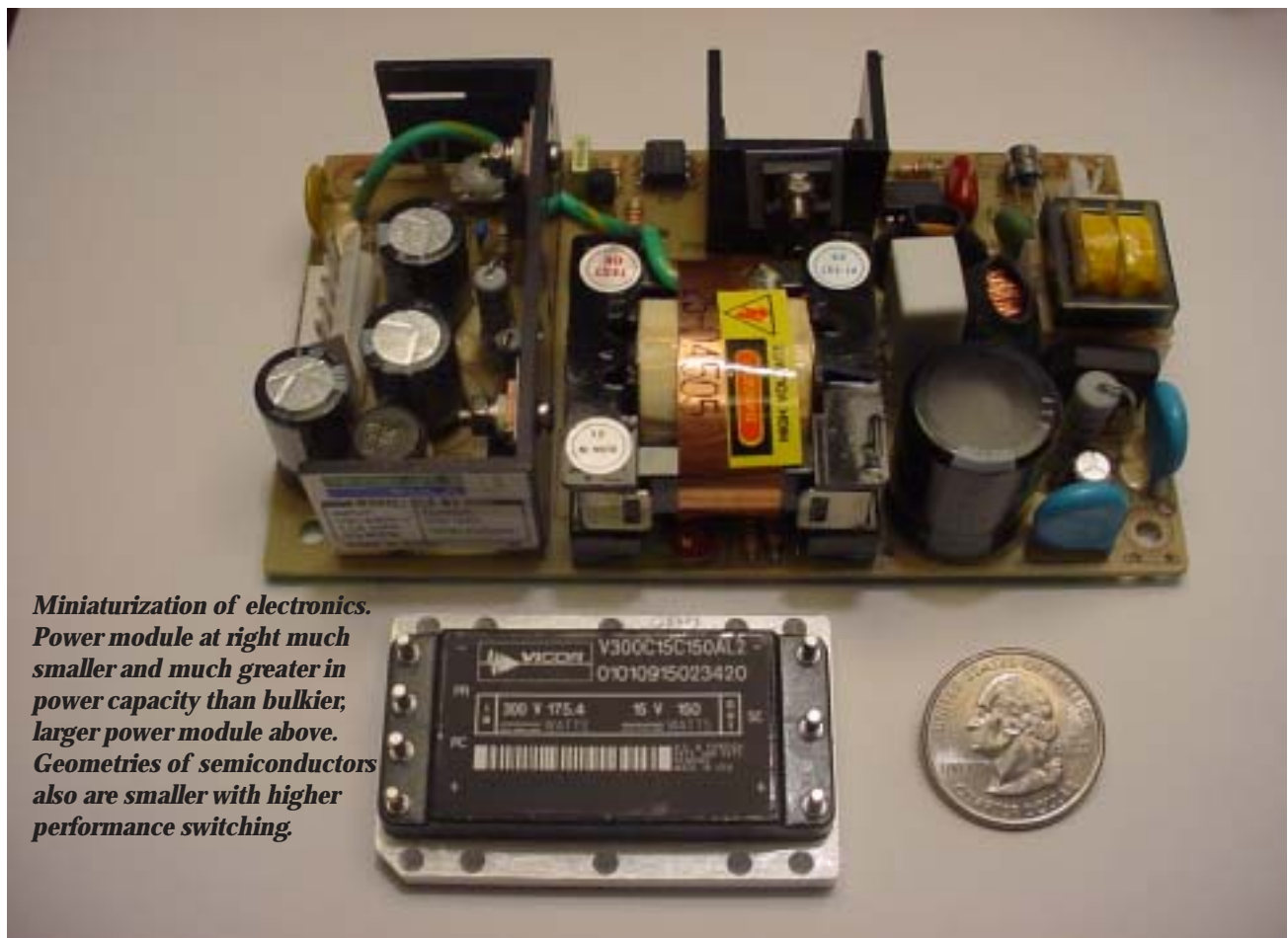
As a senior R&D engineer at a massively parallel supercomputer (hypercube) company, I was brought in to resolve unusual failures in the high density hard disk array subsystems. These systems had hundreds of drives with redundant power modules providing 12V and 48V per disk rack. The disk rack power modules were experiencing blown Field Effect Transistors (FET) or blown microfuses in the high efficiency DC to DC converters. Failure analysis of the internal damage within in the power modules only deepened the puzzle.

Tracking down the killer mechanism

At first, our senior mechanical designer, Randall U-Ren, tested the units for any thermal anomalies as this can give the same symptoms by overstressing devices. All of the power modules were operating comfortably within specifications as the airflow cooling kept modules well below the max limits. Yet failures would continue, but in clusters or groups at a time. Some days the failures wouldn't occur regardless of how the system was exercised. This is where I was brought in to resolve this issue as production was on hold pending rectification of any design anomaly.



View of burned Field Effect Transistor (FET) commonly used in DC to DC converter power supplies.



Miniaturization of electronics. Power module at right much smaller and much greater in power capacity than bulkier, larger power module above. Geometries of semiconductors also are smaller with higher performance switching.

After understanding the damage, although bizarre, we started to instrument the system looking for an external type of energy that somehow makes it through all of the AC filtering and enables the internal damage. The instruments were set to capture and store the information like a trap. Set and wait. What was found was very unusual.

By triggering on any small disturbance on either of the 12V or 48V regulated power we could then capture incoming AC lines for clues. Waiting for a trigger could take days. When one finally registered we observed that the 12V and the 48V were ramping upward as if the power module was pumping energy as fast as it could convert. Needless to say this was well out of operating conditions. Looking at the incoming AC captured waveform there was a near perfect sine wave - nothing. Either something of great energy was getting into the power module - somehow - or the power module itself had a very intermittent design defect.

Working with the manufacturer of the module the R&D engineering staff were baffled at the behavior of the units. They believed that there was a real problem as they conducted the failure analysis on

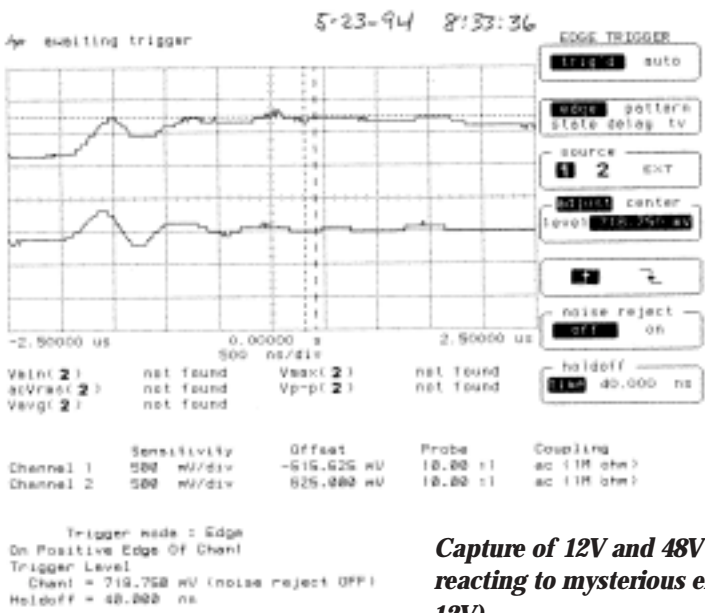
the destroyed FET's in the unit. Yet these modules have been in production for quite a time without any reported failures as ours were exhibiting.

The mysterious energy indicated that it was external to the power module since the 'pico-fuses' (very fast blow micro type) inline with incoming 300VDC to the modules were usually blown. Further 'upstream' in the incoming AC powerflow the sub-system AC fuse had no damage. Whatever was passing into the system was not being stopped by heavy protective filtering torroid inductors and large bulk capacitors in the AC to unregulated 300VDC module.

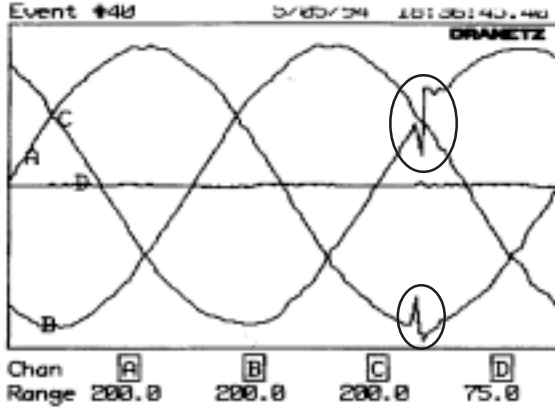
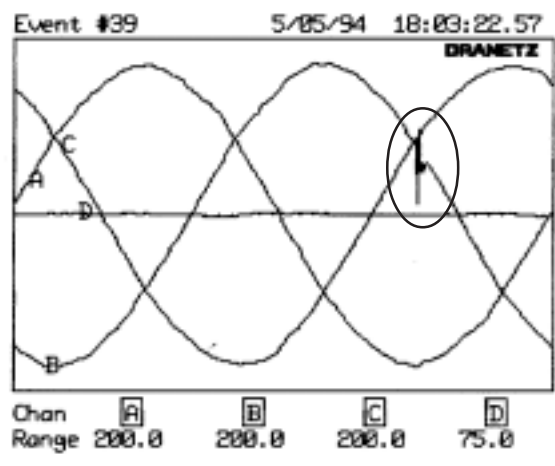
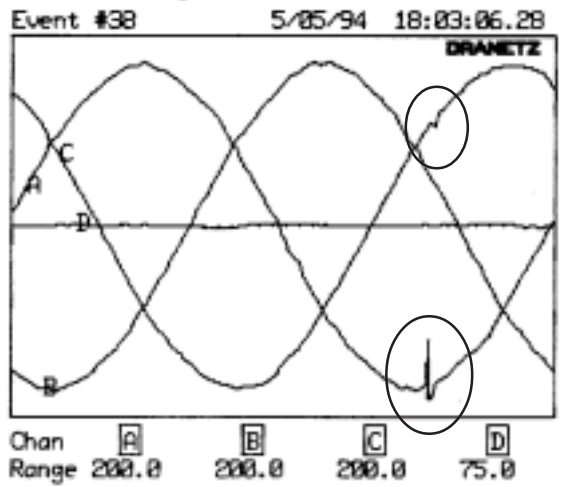
In parallel to our efforts a consulting company specializing in power analysis was hired to monitor the building AC power to our production facilities. Dranetz 3 phase AC instruments were installed on the lab AC power to capture any disturbances. Their instruments captured a number of typical transients on the AC power but the AC/DC filtering section attenuated the transients as designed (some of the captures shown on next page). Comparing their trigger log of timestamped captures also identified that the power module anomalies were not

happening from the typical AC power disturbances (transients, dips, or glitching). In light of the information the consultants were at a loss in explaining what may be occurring on the AC power. They began to look over my shoulder in the growing mass of instruments I had hooked up to systems trying to track down the anomaly. The crowd was growing in mystified experts.

A triggering mechanism 'breakthrough' developed when a special signal observation method was constructed. Taking a digital signal processing (DSP) board, sense divider resistors, and writing custom filter code for the DSP unit created a flexible trigger unit which allowed observation of very small variations on the incoming AC power. As events were far and few between, the new capture system was tested in the lab to ensure it was operating properly. Validating to satisfaction, the intricate capture unit was instrumented to a power subsystem. One day later we had a trigger and data to analyze. The oscilloscope which captured the zoomed in view of the incoming high voltage DC power had a very small disturbance for tens of milliseconds. The waveform was a fraction of a volt (few hundred millivolts). Yet with this small disturbance the output of the power module was ramping at a wild rate. This did not make any sense as this was a tiny disturbance in a 300V DC incoming voltage that had a 60hz 2V ripple as part of the normal design conditions. This is an equivalent of a flea on an elephant.



Capture of 12V and 48V output from power modules reacting to mysterious energy. (upper trace 48V, lower 12V).



Facility 3phase AC power with recorded 'transients'. These were eliminated as failure mechanism source to the mysterious energy.

What added to the bewilderment was the DSP system. Testing in the lab characterized the amplitude and width of what signal would trigger and what would be ignored. This tiny disturbance shouldn't have triggered the DSP unit. Somehow this small disturbance was causing micro-electronics to behave in a completely abnormal condition.

Consistently the system would trigger on these tiny disturbances with the same behavior of the power module. We found the source but could not explain the mechanism.

AC power filtering units, isolation transformers, and other filter experiments were tried but none would stop these small bursts from entering the system. When these bursts entered, the same outcome resulted; either a blown micro fuse (used to protect the FET's) or the FET's were toast. We discovered later that when a fuse was blown the FET had already sustained damage and in its weakened state would fail under normal operating stress.

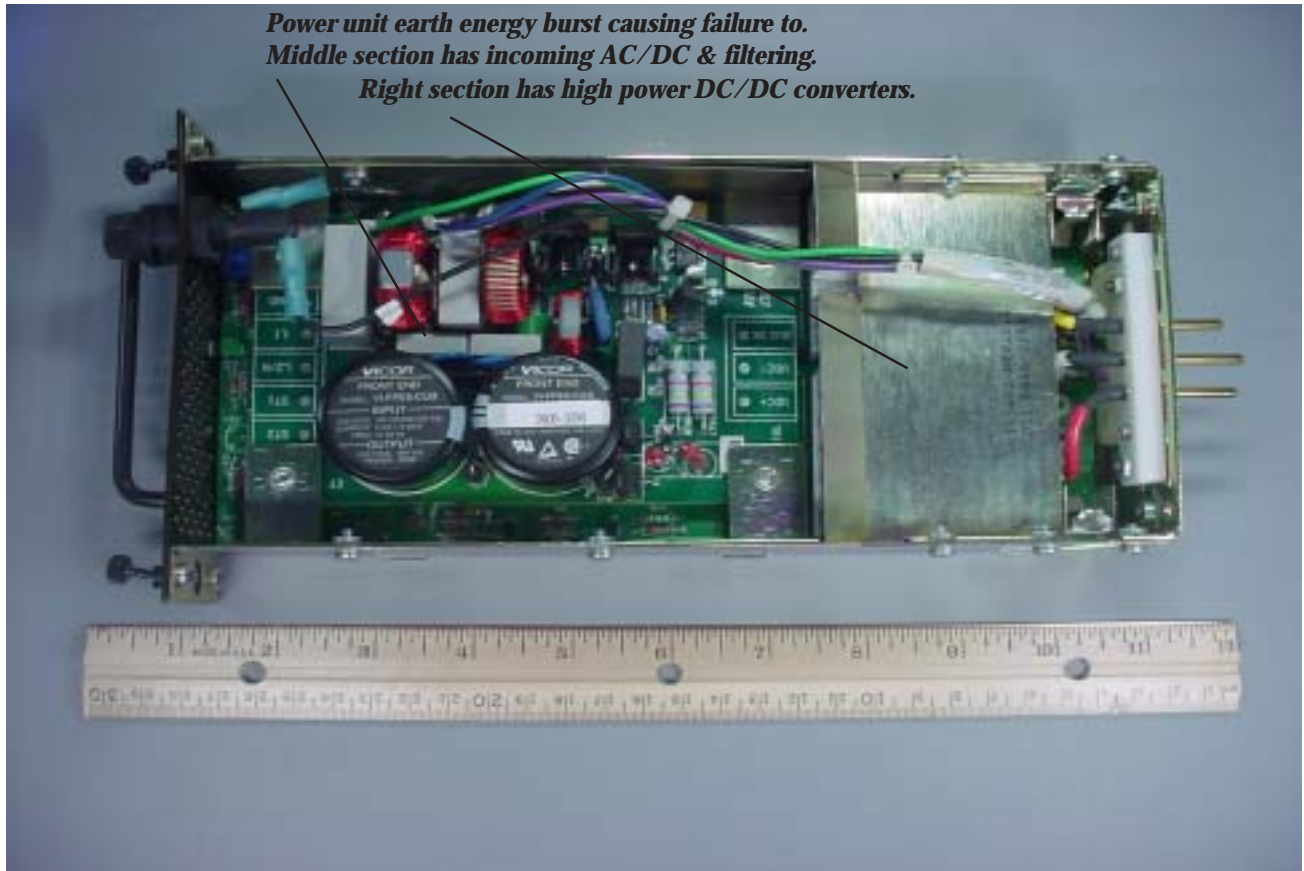
We then focused on analysis of the damage to the FET's. The damage mirrored an extreme condition of 120C thermals where a phenomena of 'excess electron & hole carriers' interfere with the normal conductive behavior of the semiconductor (conduction becomes 'intrinsic'). The device could self destruct in these extremes. Yet thermal testing

demonstrated the modules to be well cooled in the system at the time of failure. The clue that began to unravel the mystery was how the DSP system responded to the tiny burst and could 'see' it.

The DSP system front end amplifiers were based on Operational Amplifier (OP AMP) technology to an Analog to Digital (A/D) converter. If a small signal disruption could cause a FET to effectively mimic a heavy excitation mode (from valence to conduction) then the OP AMP and A/D converter would also behave unpredictably to the same energy.

To excite semiconductor material to the equivalent excess charge carrier state would require energy that contains a rich spectral content such that the lattice structure of the doped crystalline depletion region transitioned into a form of a near ionized state. (similar to technique used in research via spectral excitation of solid materials by multiple lasers tuned to atomic frequencies in the target material - to ionize atoms of interest., Resonance-Ionization Mass Spectrometry (RIMS) A spectral rich burst will do the same to semiconductor material. Observing the power transferred to the FET during the small incoming signal gave an indication that the energy content was high. Yet the IR drop (voltage) was very small. This defied the normal ohm's law behavior unless the resistance -'R'- of the mass the pulse

***Power unit earth energy burst causing failure to.
Middle section has incoming AC/DC & filtering.
Right section has high power DC/DC converters.***



traveled through was not the same. The DSP resistor divider unit also showed that the energy penetrated with a different drop (IR) than what the metal film device as designed to. This energy pulse passed in a very low conductive path that in itself occurs due to the nature of the pulse. Even with hundreds of Kilo ohms in metal film resistors the tiny signal was able easily pass through and strongly disrupt the OP AMP & DSP semiconductor devices.

The energy 'reacts' with mass.

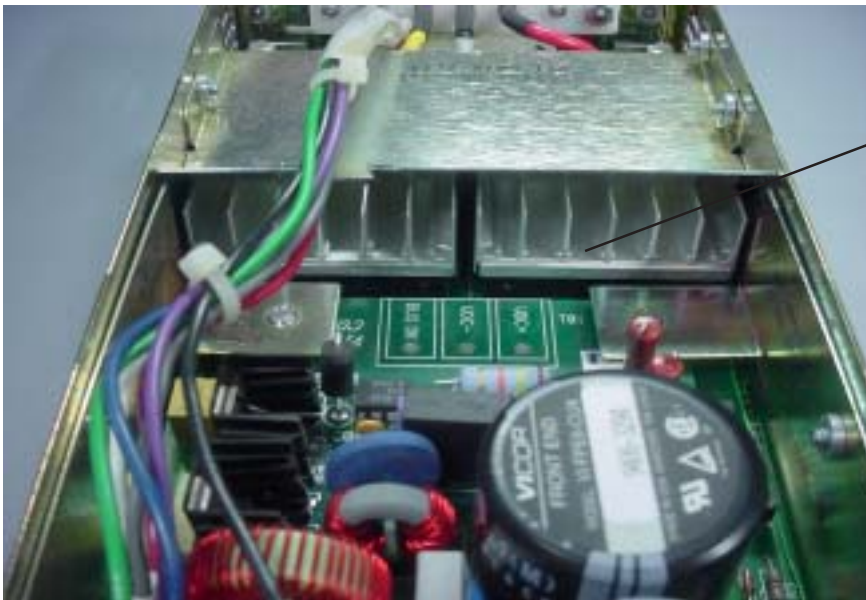
We found that miles away other site computers were crashing at the same dates and times as our systems. They too thought that the AC power was to blame. Brand new UPS units and AC filters were installed to no avail.

The energy bursts were from the Earth

These unusual energy bursts were originating from the earth. They would enter into the power grid and attack any sensitive micro-electronics. Larger and older technology with bipolar transistors or slower FET's were not as sensitive to the energy transients. This was confirmed by observing all of the power subsystems (computers, routers, etc) during the time the bursts were recorded.

The power of these bursts would have to be very strong indeed to spread throughout the local region and not be attenuated from the very low impedance of tens of thousands of electrical loads (devices - AC powered).

Analyzing all of the failure data and timing showed that the earth bursts occurred following major solar flaring events by three days (see plot next page).



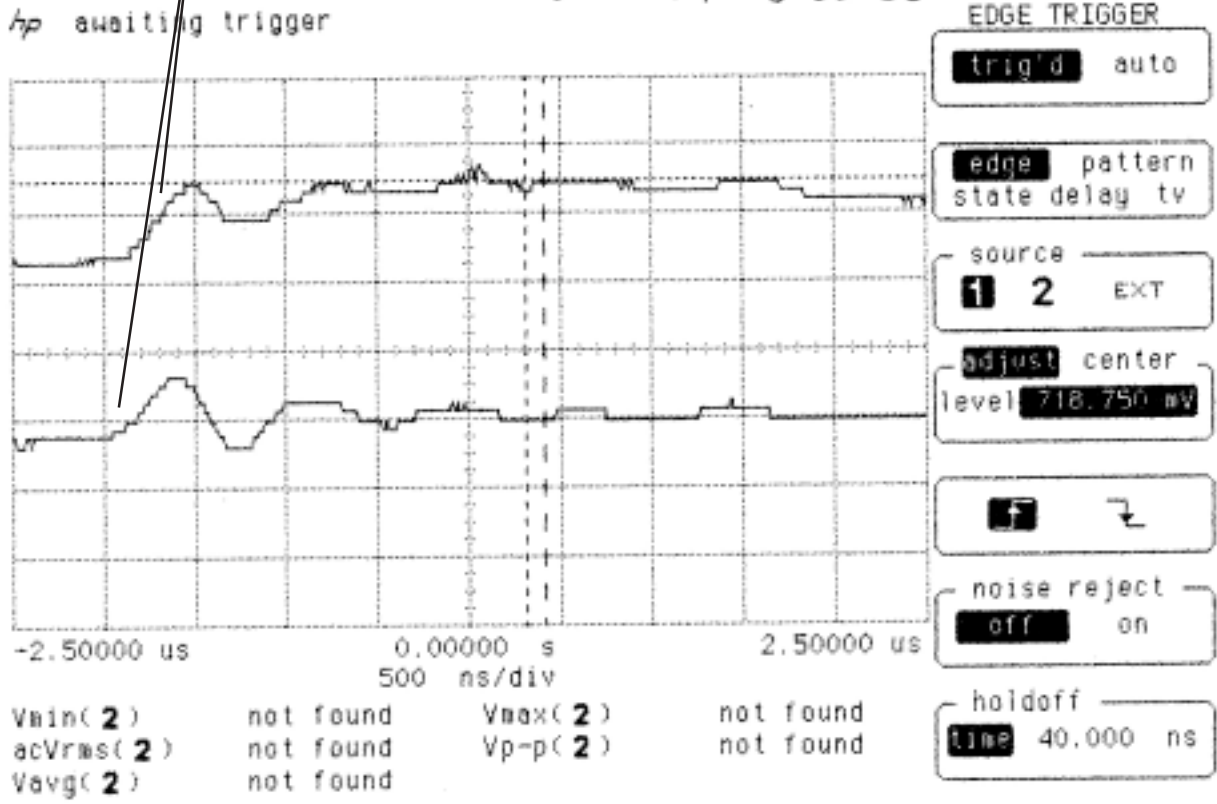
Switcher FET burned inside of power module (DC/DC converter).

Digital Signal Processor unit. Used to analyze and trigger on energy burst as it entered system.



Top waveform shows 48V module output increasing, bottom waveform also shows disruption of 12V module output.

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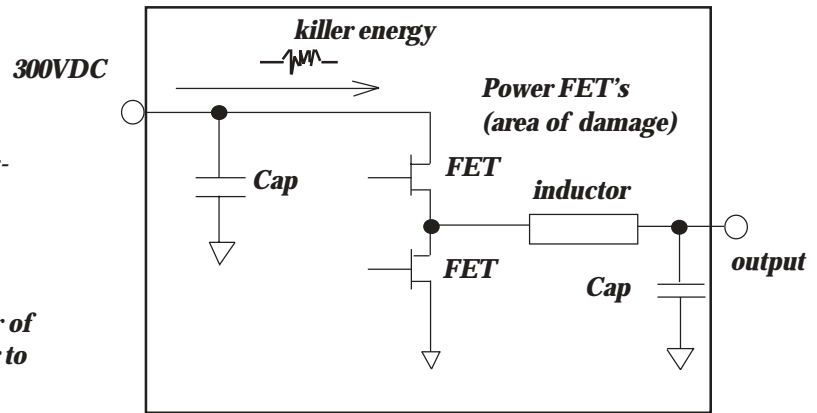


	Sensitivity	Offset	Probe	Coupling
Channel 1	500 mV/div	-515.625 mV	10.00 :1	ac (1M ohm)
Channel 2	500 mV/div	625.000 mV	10.00 :1	ac (1M ohm)

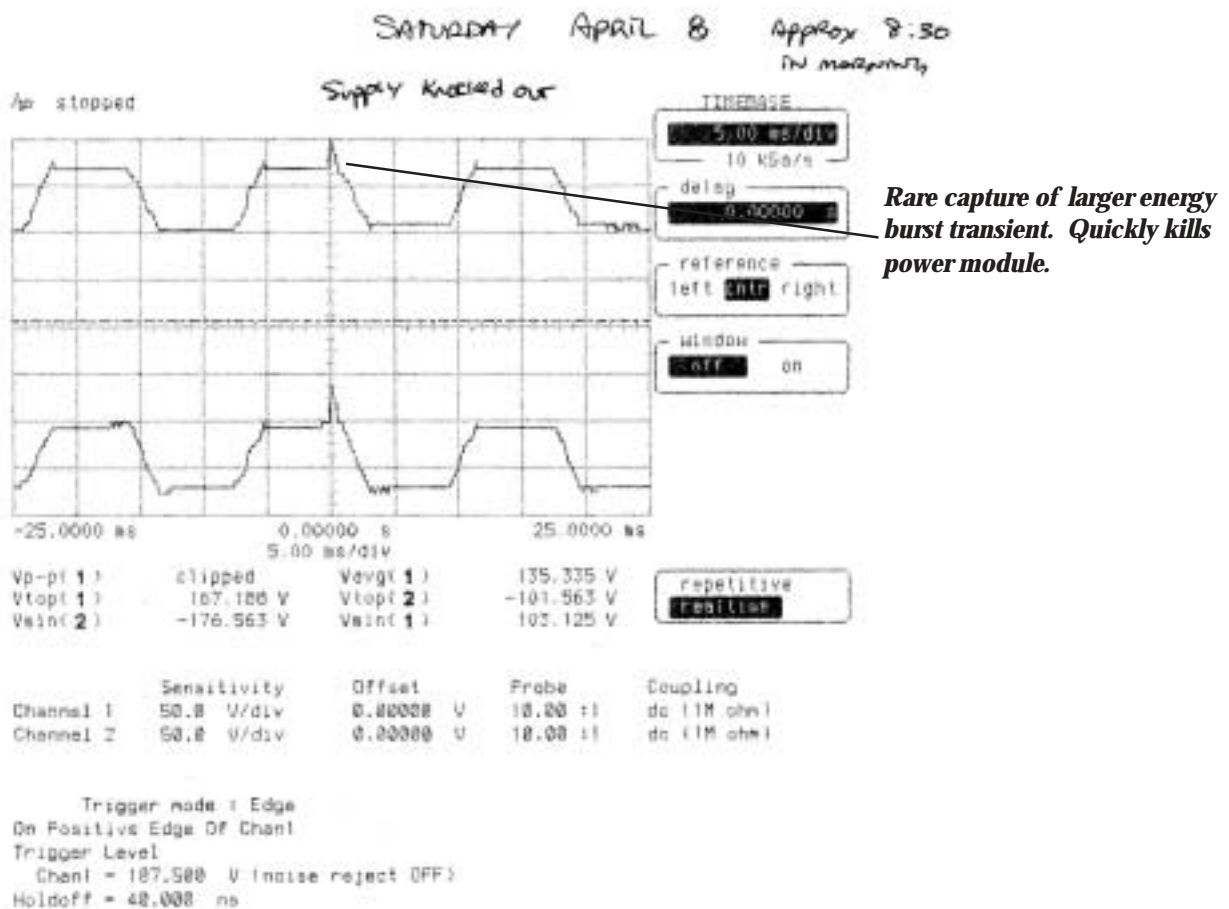
Trigger mode : Edge
 On Positive Edge Of Chan1
 Trigger Level
 Chan1 = 718.750 mV (noise reject OFF)
 Holdoff = 40.000 ns

Trigger result from 'killer' energy reaching Power Module in supercomputer disk array. Waveform shows erratic behavior of internal power FET devices by the output waveforms.

Killer energy enters through 300VDC path & results in destructive behavior by power FET's. Behavior of waveform to FET destruction indicative of excited excess electron/hole conduction (intrinsic) where normal behavior of FET operating conditions similar to extreme thermal excitation.



(simplified power module view)



Earth geomagnetic storming

The earth experienced minor/major geomagnetic storming three days prior to the 'killer' impulses. That is why we had difficulty capturing impulses as it was tied to earth cycling and timing. Using the sensitive DSP instrumentation was only then we were able to study smaller less damaging impulses, yet still quite disruptive to the power module.

Energy equivalent of 1100V spike

We conducted studies to understand the equivalent energy content that would result in the same failure outcome - destroyed power module switcher FET. It wasn't until an 1100 volt transient was zapped into the system that we reproduced the equivalent damage to the switcher FET. To realize the full power of these unusual earth transients, multiply the tens of thousands of loads that this energy goes through on the power grid with little to no attenuation. The alternative is to model the injection as a point-source vs a wide area simultaneous injection. Either way, the transient energy is very strong and ends up affecting a wide area in the power grid.

Energy 'interacts' with Mass

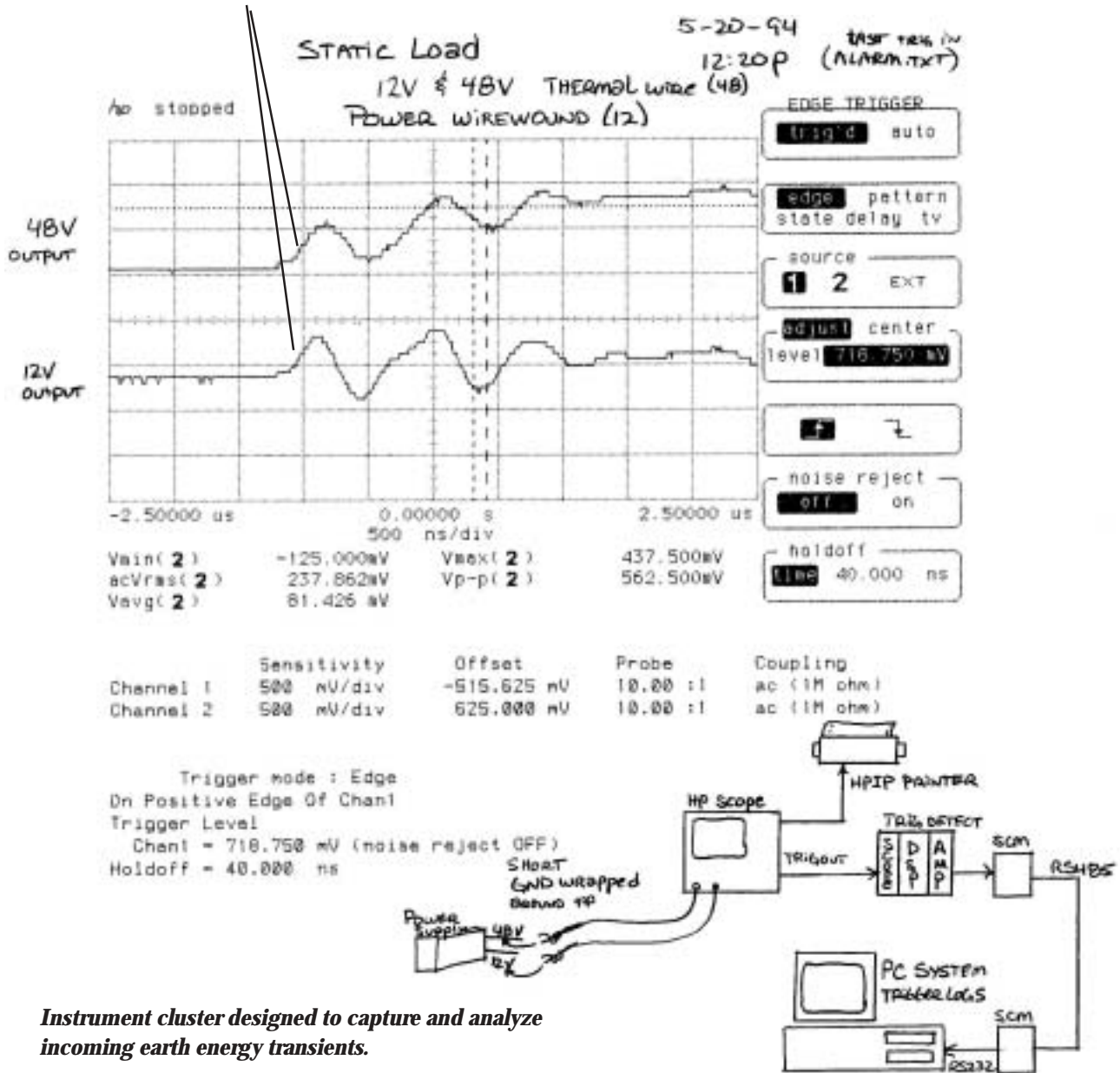
It was found that these impulses interact with mass resulting in a strong form of ionization within (for conducting metals) or a 'charge polarization' in dielectric materials. Designing mass to sense these reactions results in a Mass Resonant Sensory Device (MRSD). Building upon this technique yields devices that sense down to the small earth impulses.

The study of this original failure mechanism has been the foundation to a new form of technology and been the basis of the number of years of earth research using MRSD devices.

'Killer' is powerful local SPI

Research has revealed that powerful Single Phase Impulses are the 'killers' of micro-electronics. They enter into the power grid and wreak havoc on subsystems that have just the right geometries in the micro-electronics. In areas of strong precursory activity with these types of SPI's there's likely to be unexplained 'resets' or 'failures' of electronic equipment. Unless MRSD 'shunt' techniques are employed, there aren't many AC filtering devices that will be able to stop these bursts.

Incoming earth energy transient causes power FET's to switch wildly - boosting output voltages.



Instrument cluster designed to capture and analyze incoming earth energy transients.

Start of Earth Research

Exposed to such a unique form of energy initiated an intense curiosity as to why or how could the earth operate in such an 'electrical' nature. The chapters following in this book are the result of nine years of development of electronics, instruments, and collection of data associated with seismic activity.