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Wayne Tustin

Voice of the President

## Thermal Management Short Course

by Joel Newberger

An example of a knowledge gap in thermal design is associated with naturally-cooled circuit boards. Natural convection heat transfer equations associated with vertical surfaces do not apply to components that are mounted on vertically oriented printed circuit boards. As a result, heat transfer analytics taught at the university may not apply when characterizing circuit board thermal profiles.

Another example: naturally-cooled pin-fin heat sinks (here, textbook material is very limited). See Figure 1. Thermal boundary layers grow on each pin; they

collide with each other, as well as with the host wall. Discrete electronic devices are fastened directly to the host wall with heat conductively transferred to the heat sink. In this heat sink environment, classical textbook calculations do not provide proper design guidance; however, use of test data (an information bridge), when available, provides a safer and more reliable design.

ERI's thermal design courses bridge such information gaps so that participants will meet their program goals despite uncertainties in textbook design data. Courses are available for equipment

cooling-design utilizing

- air or liquid or spray coolants,
- indoor/outdoor enclosures,
- telephone racks,
- avionics and
- equipment mounted on surface ship/submarine platforms.

The courses cover a wide range of topics that can be found at ERI's complete course

**Is that the same Wayne Tustin who taught a vibration class I attended in 1961?**

I love getting e-mails that start off with that kind of question. 1961? Until October that year, I was still at New Haven, Connecticut, with MB Electronics, which now is called MB Dynamics, near Cleveland. Early that year, I taught several shaker-oriented courses for MB.

My family and I spent a week driving to Santa Barbara, California, where I reported to Raytheon. Rather soon came a massive layoff, perhaps 25% of the workforce. An opportune time and place to open a school known as Tustin Institute of Technology offering, among other subjects, training in vibration and shock testing. Unadvisedly, in the late '80s we changed that to Tustin Technical Institute. Unadvisedly, we sold it in 1990. I thought I was ready to retire.

Base 1" x 1.75" x .125"thk  
Pins .125"dia x .625" height above base  
Pins center-to-center spacing .25"

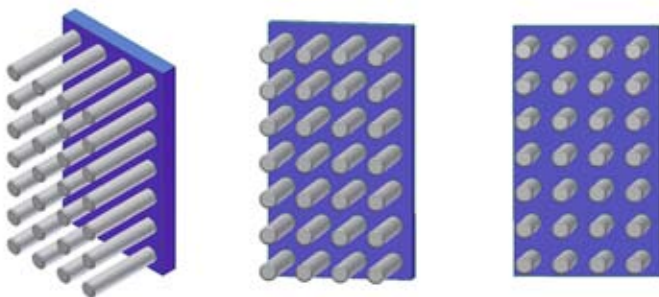
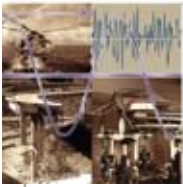


Figure 1 - Pin Fin Grid Array



listing in PDF located at [http://www.equipment-reliability.com/course\\_outlines.html](http://www.equipment-reliability.com/course_outlines.html). Many engineers have participated in these educational "bridge" courses. Their organizations have benefited from cost-effective, highly reliable mechanical designs.

When a one or two semester course is offered at the university, the depth to which material is covered - with numerous examples of practical application - is limited by course time constraints.

However, short courses, of one-to-five day duration, that couple and enhance:

1. what has been learned at the university with
2. that required to be productive at the work place

*Joel Newberger is President of Thermalogics, Inc., and a principal in SNA Engineering. SNA specializes in mechanical design/packaging and in thermal/structural analysis of electronic equipment. For more information about this ERI specialist visit [here](#).*

are more successful at bridging the educational gap. These short courses are highly valuable to entry and to some senior level engineers. Some engineers require a refresher course. Some, new to the tasks of mechanical design driven by thermal considerations, require an introduction. ERI courses accomplish these tasks because they identify knowledge "gaps" and bridge the gaps with practical information.

After decades of providing thermal management/electronic packaging consulting services, I realize that using newly developed computer hardware/software can bring greater on-the-job productivity. However, engineers utilizing such computer programs may not be commencing with proper thermal and dynamic computer models.

ERI, Equipment Reliability Institute, was born in 1995, offering training in vibration and shock testing. A few other subjects have been added, all relating to reliability and durability of equipment.

I'm very fortunate, enjoying good health and an occupation I love. Lately I've let our specialists teach overseas, but I still present classes in many US cities throughout the year.



### Allan G. Piersol 1930 - 2009

The entire shock and vibration community has lost another good friend... Allan G. Piersol.

Allan died March 1, just a month after shipping to McGraw-Hill the final material for the Sixth Edition of the famed Shock and Vibration Handbook, due out late this year.

His family, neighbors and many of his personal and professional friends gathered at Fins Creekside Restaurant, Calabasas, California on March 15th to celebrate Allan's life.



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## COTS Vibration Testing

*by Wayne Tustin*

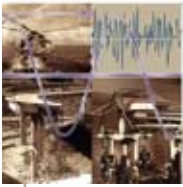
Designs that use COTS (commercial-off-the-shelf, a military term) products must take into consideration the harsh environments in which these commercial devices may be used. One of the common sources of COTS system failure is vibration. COTS equipment vibration testing can mean the difference between system success and failure.

Vibration testing identifies design flaws and identifies potential failure before the equipment is fielded. To perform an adequate vibration test on an existing COTS circuit card or "black box" requires at least 6 pre-production units. These units will be subjected to a variety of experiments, including Step-Stress tests, development tests and temperature ramping.

Testing requires familiarity with three types of standard environmental laboratory equipment. Shakers are controllable source of vibration. Test fixtures, which are typically custom designs, physically mount the hardware to the shaker. Accelerometers are attached to the fixture to sense input vibration.

### No MIL Standards

Just a few years ago, it was typical for military customers to specify a Test Method (such as 514) within a standard such as MIL-STD-810. Tables and charts would indicate test severities, frequencies and durations appropriate to various locations on aircraft, tanks, etc. And most commercial test labs would have known exactly what to do.



The COTS initiative has changed that. Now the norm is to test a commercial item that was originally intended for desk or similar non-threatening use. It's hoped the commercial product will survive the warranty period while mounted on some MIL vehicle or other threatening application. Vibration testing can improve the odds that the device will survive. Numerous commercial test labs can provide experienced test personnel, a shaker system and appropriate mounting fixtures.

### Step Stress Testing (SST)

Step-Stress Testing (SST) is a type of environmental test. Let's examine the vibration portion. For SST the product is mounted on a fixture which is attached to a shaker. Supply power to the product, and turn it on. After power-up, monitor some of the hardware's functionality to determine if it fails even momentarily. If the product is functioning, the shaker is started, preprogrammed for 1g RMS

***Don't Stack Resonances***  
***An important***  
***commandment in***  
***dynamics is "Thou***  
***Shalt Not Stack Thy***  
***Resonances!"***

random vibration 10-2000 Hz. At this point observe hardware electrical output to identify any misoperation. Misoperation in the product indicates trouble. If finger pressure at some location restores operation then there is a poor connection that needs to be identified. If a resonating part moves, friction or damping needs to be added. If a part flies off it needs to be secured. Experienced lab people have seen similar failures and will be able to suggest "Band Aid" fixes. Shake the product again (on the same unit or substitute another unit) at 1g RMS. If it

survives at 1g RMS no further testing is required.

### Is Developmental Testing Allowed?

If the "Band-Aid" fixes don't work, further testing, properly called development testing, is needed. Management approval for further testing should be pursued, because another phrase for COTS is NDI (non-developmental item) and there may be at least a temporary edict against development testing.

It is important to understand how the hardware responds to all-frequencies-at-once random vibration. This is best done by one-frequency-at-a-time sinusoidal testing. The shaker is reprogrammed to slowly sweep, for example 5 to 2,000 Hz. 1g RMS intensity is held, measured by an accelerometer on the fixture. Several response accelerometers should be mounted at any critical locations on the hardware. These outputs are recorded. Resonance is the problem at vibration frequencies where it is found (a strobe light is helpful) that response > input or where response accelerations > 1g.

### Don't Stack Resonances

An important commandment in dynamics is "Thou Shalt Not Stack Thy Resonances!" That is, when a printed circuit card (PCB) is discovered to have certain natural flexing frequencies, it should not be in a box whose natural frequencies are nearby. The box should not be located on a platform where structural vibration approaches PCB or box natural frequencies. In the best case, the platform vibration is already known and can be determined. If resonances are stacked, some design changes will be needed. Such changes are outside the scope of this article.

### Back to SST

Once the hardware operates correctly at 1g RMS with random vibration, it should be rotated 90° into another (and later the third) axis. Obviously, simultaneous multi-

ERI's Vibration and Shock Group. You can comment on multiaxis vibration testing, on hammers for repetitive shock (as in ESS, HALT & HASS). Perhaps you will suggest a topic. Perhaps under Jobs you can find employment or an employee.

### Upcoming "open" courses

Wayne and several ERI specialists will teach "**Fundamentals of Random Vibration and Shock Testing, Measurement, Analysis, Calibration, HALT, ESS and HASS**" at the following locations:

May 11-13, 2009,  
Dayton, Ohio

June 1-3, 2009,  
Boxborough, Massachusetts

July 14-16, 2009,  
Hillsboro, Oregon

August 17-19, 2009,  
Santa Barbara, California

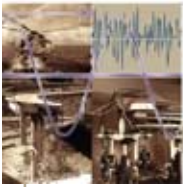
September 15-17, 2009,  
São José dos Campos, São Paulo (Brazil)  
*(presented by Steve Brenner)*

October 13-15, 2009,  
Santa Clara, California  
*(presented by Steve Brenner)*

November 4-6, 2009,  
Frederick, Maryland

Herb Lekuch will be teaching "**Isolating COTS Equipment aboard military vehicles**" at:

September 1-3, 2009,  
Singapore  
(3-day course)



axis shaking will save handling.

At some point, when the hardware can operate satisfactorily at 1g RMS random in any direction, the vibration should be increased. The intensity should be step-increased to 2g, 3g, etc. in each axis. As before, everything that fails needs to be fixed. The product should be made as rugged as possible in the available time.

### Combine with Temperature Ramping?

Step-stress testing is even more effective when combined with rapid (20 to 50° C per minute) thermal ramping, stepwise increasing temperature extremes toward

50°. Rapid expansion and contraction of PCBs and components helps to reveal latent or hidden defects. It is better to find defects in the lab than in the field, under warranty. Temperature ramping also ensures operation over a range of field temperatures.

### How much is enough?


This question is not easy to answer. The general rule is that more is better. The good news is that changes that dramatically increase dynamic ruggedness are often achieved with zero increase to manufacturing cost.


Wayne Tustin, ERI's president, can be reached by e-mail or phone (805) 564-1260.


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## Test Lab Musings (part 24)

by Robert L. Renz


 If you really want to make life easier, buy an adjustable coax stripper. I wasn't able to find any pre-set strippers that would my connector's dimensions, but an adjustable stripper (that cost more than the crimper!) did fine. The end result is that it now takes only a few moments to make the exact length RG-58 cables I need. The material cost is higher per cable than purchasing a complete cable, but I can get it in 10 minutes.

 If your lab uses thermocouples, consider purchasing a shielded gas thermocouple welder. I use type T thermocouples – one wire copper, and the other constantan-copper-nickel alloy. The welded end usually requires about ¼" or so of bare wire ends. Place them side by side in a copper clamp, adjust with a microscope and tweezers if they are small (perhaps 40 gauge), and place them into the welder. An argon purge is followed by a timed arc from a tungsten electrode. The end result is a perfect small weld between the two leads. They CAN NOT be soldered – soldering introduces more metals into the junction, and that will affect the accuracy of the thermocouple. The other end of the thermocouple is connected to a data logger. Type T thermocouples have one lead with blue insulation, and one lead with red insulation. The blue lead (copper) is the high (+) lead, and the red lead (constantan-copper-nickel alloy) is the low (-).

 These welders utilize an argon atmosphere and a tungsten electrode to weld thermocouples in only a few seconds. Make your own, instead of buying a pre-made thermocouple at perhaps \$15. Your material cost is only about \$ 4-5 for each 10 ft thermocouple. The real saving is in time: perhaps 10 minutes versus preparing a special order. You also save since it's now easy to reuse a thermocouple – snip off the tip if there's any mounting epoxy left on it, and weld the tip again. When you mount a thermocouple onto a test specimen, glue the bonded connection into place

September 22-24, 2009,  
San Jose, California  
(3-day course)

September 29 - November  
17, 2009,  
College Point, New York  
**(new course format: once  
a week on Tuesdays)**

 *Take advantage of our early-bird discounts and save up to \$200 when your enrollment and payment reach ERI one month before the course starts. Sign up now!*

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### ERI offers MIL-STD 810G Training

Four-day classes will meet at Santa Barbara (CA), October 19-22, 2009 and also at Bohemia (Long Island, NY) November 16-19, 2009.

This course aims at professionals who need to **perform, witness or specify** environmental testing in accordance with the new "G" revision to the venerable Military Standard 810.

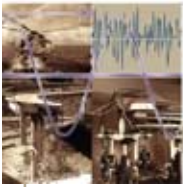
Training will cover all of the Dynamic and Climatic tests described in 810G. It will focus on performing the tests.

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### Optimize HALT Results with Best Practices

That's the title of a useful article in the March 2009 issue of *Evaluation Engineering* magazine. Readers might want principal author Ted Kalal to come teach or consult at their facilities.

Here is a link to the article.



with either 5-minute epoxy or a cyano-acrylate adhesive. Later, when removing the thermocouple, removal of the adhesive blob usually damages the thermocouple. With a welder available, we just snip off the tip, and reweld the ends.

**■** Thermocouples are often needed for RDT (Reliability Demonstration Tests), also known as combined temperature-vibration. Monitor Internal temperatures continually to ensure that the test item is being stressed sufficiently, but not over stressed.

*Robert L. Renz of General Dynamics - Advanced Information Systems at Bloomington, Minnesota.*

## Trying to Understand $g^2/Hz$



Do you or your co-workers need to understand  $g^2/Hz$ , the units of PSD or Power Spectral Density (sometimes called ASD or Acceleration Spectral Density or AutoSpectral Density)?

$g^2/Hz$  is the usual Y ordinate, plotted against the X abscissa (frequency in hertz or Hz) on graphs showing random vibration testing or screening requirements.

It's explained in Lecture 20's Video Sample on the Web (see photo).

## Seeking New Specialists

In these difficult times, some who have been laid off have decided to consult for many companies (rather than seek another job). If that sentence applies to you, please consider associating with ERI. May we hear from you?

## NDT instructor needed

Does some reader specialize in Non-Destructive Testing (NDT)? Which of the following? liquid penetrant testing, radiographic (X-ray) testing, computed tomography, ultrasonic testing, magnetic acoustic testing, electromagnetic testing, eddy-current testing, acoustic emission testing, hardness testing, magnetic resonance imaging, etc.

Would you be interested in teaching a few days, several times per year? If so, please communicate with Wayne.

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## EMI/RFI/EMC Teacher Needed

ERI needs an electromagnetic interference/ radio frequency interference/ electromagnetic compatibility teacher for occasional short (typically 3 days) courses. Please phone or e-mail Wayne Tustin.

## Seismic Simulation

Does any reader feel himself/herself to have expertise on seismic simulation? May we hear from you?

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