Cooling Methods for Electronics Design

Course No. 471

FOR WHOM INTENDED: Electronic designers and packaging specialists, environmental test laboratory engineers and technicians, specification writers, equipment designers, and quality and reliability specialists.

BRIEF COURSE DESCRIPTION: The course introduces the fundamentals and physics of thermodynamics and heat transfer. The need for thermal management in electronics design is discussed. Next, the basic types of heat transfer, convection, conduction and radiation, are introduced and then discussed in depth. Conduction is covered first, including how thermal resistance and conductivity are calculated and the effect of joints on thermal resistance. Numerous ways of improving thermal conductivity are presented in detail, and examples illustrate and quantify the effects of these methods. Convection topics include free versus forced convection, heat transfer and film coefficients of air and fluids, PC board spacing, heat sinks and impingement cooling. Classroom examples show how to calculate the thermal effects of natural convection, heat sinks, laminar and turbulent flow. A detailed discussion of pressure drop and fans follows, with examples of application to electronics cabinet design. The radiation section deals with thermal management in space, for satellite and spacecraft applications. A discussion of thermal resistance networks follows.

The latter part of the course shows how to apply this information to the design and testing of electronic and other hardware. Advances in high density semiconductor integration have placed increased demands on thermal management and packaging in electronic hardware. Since conventional methods of electronics cooling may not meet the demands of new advanced designs, the instructor will discuss some advanced cooling techniques, some of which will set new industry standards in the 21st century. Topics covered include heat pipes, thermal modeling, PC board cooling alternatives, airflow balancing and a brief review of thermal testing. A class project is included to provide supervised practice in using the course material.

The course is presented as a series of highly-interactive lecture/discussion sessions. Problems for individual and group solution are interspersed throughout the course to act as training aids and to evaluate class progress. Special-interest discussions are encouraged outside of the regular course sessions.

DIPLOMA PROGRAMS This course is required for TTI's Electronic Design Specialist (EDS) Certificate Program, and may be used as an elective for any other TTI Specialist Diploma Program.

PREREQUISITES There are no definite prerequisites. However, this course is aimed toward individuals involved in related technical fields.

TEXT Each student will receive 180 days access to the on-line electronic course workbook. Renewals and printed textbooks are available for an additional fee.

COURSE HOURS, CERTIFICATE, CEUs On-site courses can vary from 14–35 hours over 2–5 days as requested by our clients. Upon successful course completion, each participant receives a certificate of completion and one Continuing Education Unit (CEU) for every ten class hours.

INTERNET COMPLETE COURSE 471 features over 15 hours of video as well as more in-depth reading material. All chapters of course 471 are also available as OnDemand Internet Short Topics. See the on-line course outline for details.

Technology Training, Inc.
(a tti group company)
Toll-free telephone:
866-884-4338 (866-TTi-4edu)
International: 805-845-5050
E-mail: Training@ttiedu.com
www.ttiedu.com

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Course Outline No. 471

Introduction

Thermal Management of Electronics • Effects of temperature on electronic components • Junction temperature of an IC • Trends in thermal variables, industry trends • Definitions, temperature scales • Basic thermodynamics, heat transfer mechanisms • Influence of Thermophysics on Electronic Equipment Design

Conservation of Energy

First Law of Thermodynamics • Conservation of Energy • Energy Balance • Controlled Mass System, Examples • Controlled Volume System, Examples

Conduction Heat Transfer

Heat flows through a solid • Addition of Thermal Resistances: Series, Parallel, Combination • Factors affecting Joint Thermal Resistance: Roughness, Pressure • Improving conduction: Metal foils, shims, thermal grease • Effect of contact pressure and area • Contact resistance, minimizing; Example • Heat Sinks and Heat Exchangers • Properties of Thermal Plane Materials • Thermal wedge clamp; Example • Surface Mount PC Board Assembly • Metal core PC boards; materials; determining IC case to board core resistance • Thermal paths, thru-hole vias • Amplifier internal heat sinking • Thermal conductivity of : Substrate materials, IC packaging materials, Adhesives • Thermal spread angle; values for common materials; Example • Diamond heat sinks

Convection Heat Transfer

Definitions, Nomenclature • Free or natural vs forced convection • Heat transfer and film coefficients for air flow around different shapes • Convection equations • Effect of altitude • Cooling fins and heat sinks • PC board spacing, power, and heat removal; Example • Forced convection on PC boards; Example • Three methods of enhancing forced convection on PC boards • Turbulent and laminar forced convection inside shrouded fins; effect of fin tip gaps • Impingement cooling • Interleaved fins • Pin Fins plus impingement flow • Sample problems • Pressure Drop and Fans: Cooling fan selection

Radiation Heat Transfer

Fundamental Concepts: Intensity, Emission, Irradiation, Radiosity, Blackbody Radiation, Emissive power, σT^4 tables, Absorptivity, Surface Reflectivity, Transmissivity, Diffuse Gray Surfaces • Radiation exchange between surfaces • Radiation heat transfer equation • Shape or view factor curves • Radiation Exchange: Blackbody, Diffuse Gray Surfaces, Two-Surface Enclosure • Reducing Temperature of Electronics

Introduction to Thermal Resistance Networks

Thermal Resistance Concept • Conduction, Convection and Radiation Resistances • Conduction Thermal Resistance • Convection Thermal Resistance • Radiation Thermal Resistance • Thermal Contact and Interface Resistances • Thermal Interface Materials • Spreading Thermal Resistance • Series Thermal Resistances • Parallel Thermal Resistances • General Resistance Network; Example

Evaluating Cooling Requirements and Heat Transfer Mechanisms

Heat Sources and Temperature Ranges • Fundamental Electrical Theory • Defining Heat Sources and Temperature Ranges; Examples • Heat Removal Mechanisms; Examples

Electronic Cooling Design Techniques: Components

Electronic Component Descriptions: Discrete vs. Integrated Circuit, Active vs. Passive • Component Packaging: Lead Configurations, Purposes of package configuration • Component-to-PCB Mounting Methods • Thermal Specifications of Component Packages • Junction-to-Ambient Thermal Resistance (θ_{JA}: Measurement Technique, Measurement set-ups • Junction-to-Case Thermal Resistance (θ_{JC}) • Junction-to-Board Thermal Resistance (θ_{JB}) • Parameters Affecting Thermal Performance

Electronic Cooling Design Techniques: Printed Circuit Boards

Introduction to the PCB • PCB Types and Physical Characteristics: Single- and Double-Sided PCBs, Multilayer PCBs, Method of Attaching Components • PCB Design for Thermal Performance • PCB-Chassis Mounting Methods • Heat Sinking in Solid and Hollow Core PCBS – Example of Thermal Assessment • Thermal Design Concepts for Surface Mount Multilayer Boards: IC Package Configurations, Thermal Characteristics—Surface Mounted Piece Parts, Pedestal and Via Hole Conduction, Thermal Circuit Comparison, Heat Exchange Fin Geometries, Wedgelock Fastener Comparison, Typical Digital Board—Solid and Hollow Core, Hollow-Core Board Heat Exchange Study

Electronic Cooling Design Techniques: Chassis and Racks

Chassis and Rack Designs • Enclosure Packaging Examples • Cooling Air Parameters • Sample Electronics Cabinet Cooling Problem • Pressure Drop in Electronic Cabinets • Typical Electronics Enclosures • Pressure v. Airflow Relationship for Various Enclosures • Fan Selection: Internal Flow Considerations • Design Discussion • Relationships Among Heat Source, Heat Exchanger, and Cooling Air Stream • Increasing Air Velocity Through the Heat Exchanger • Determination of Cabinet Ventilation Area for Free Convection • Buoyancy Pressure Formulas • Discussion of Flow Resistance Coefficient; Sample Problem • Typical Cooling Methods for Commercial Electronic Cabinets; Example • Centrifugal Blowers • Fan Characteristics

Special Cooling Applications

Advanced Cooling Techniques: Boiling Dielectric Liquid System, Thermal Electric Cooler • Semi-Passive Thermosyphon • Semi-Passive Falling Films • Simulated Electronic Chips in Dielectric Liquid: Pool Boiling, Flow Boiling, Liquid Jet or Spray Cooling w/ Boiling • Micro and Mini Channel Cooling: Simulated Electronic Chips with Attached Heat Sink • Heat pipes: Sinks for electronic component cooling, Fluid Compatibility, Field experience. Constant-conductance heat pipe, Types of groove and wick configurations • Diode heat pipe types: Liquid trap, Liquid blockage, Gas blockage • Variable-conductance heat pipes (VCHPs): Capillary pumped loop (CPL), Comparison of VCHP and CPL performance, Analysis: Heat pipe capacity, System pressure drop, Thermodynamic considerations, Working fluids, compatibility • Testing, applications, performance, references • Micro heat pipes fabricated in silicon wafers

Thermal Modeling

Overview: Why perform thermal modeling?, Content and Level of modeling detail, Modeling or testing? Or both? • Thermal Modeling Approaches: Analytical Hand Calculation, Nodal Network and Thermal Resistance • Thermal Modeling Examples • Finite Element (FEM) or Finite Difference Modeling: Basic Steps to Setting up a Finite Element Model, FEM Thermal Analysis Example • General Steps in a Thermal Analysis • Commercial Thermal Modeling Software Packages

Thermal Testing

Overview • Thermal Equipment: Instrumentation, Thermocouples, RTDs, Thermistors, IR non-contact probes and cameras, Liquid crystals • Test Chambers and Systems • Thermal Testing Fundamentals • Electronic Cooling Testing Examples

Summary, Final Review, Award of Certificates for Successful Completion

Technology Training, Inc.

E-mail: Training@ttiedu.com • http://www.ttiedu.com