USE OF HEAT PIPES IN ELECTRONIC HARDWARE

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GOALS

In its continuing effort to reduce cost associated with space hardware development and production, MSFC is developing various standard items of equipment that show promise of significant savings in development dollars for use on future missions (Fig. 1). Among these is a modular, multiple output power converter which can be tailored to meet specific mission requirements with minimum development cost and risks. The converter is designed to convert a bus or distributed voltage to various regulated voltage levels required by a user with a minimum of hardware changes.

- DEVELOP A MODULAR, MULTIPLE OUTPUT TYPE CONVERTER FOR USE AS NASA STANDARD HARDWARE
- DEVELOP ADVANCED HEAT REMOVAL TECHNIQUES FOR POWER PROCESSING EQUIPMENT

Figure 1. Goals.

To further improve performance and reduce size and weight, the converter package design utilizes advanced heat removal techniques, namely heat pipes, to remove internally generated heat more effectively than conventional methods.

LOAD CENTER CONVERTER (LCC)

Description

The LCC consists of a mainframe chassis with interchangeable, plug-in regulator modules. The mainframe chassis serves as a common support base and distribution chassis for the regulator modules and contains the housekeeping power supply and input filtering. The plug-in modules contain the output regulator including the power switching elements and the associated drive and control circuitry. Each output regulator module is capable of up to 100 W of output power at a specified voltage level of 4 to 80 Vdc.

The LCC shown in Figure 2 is the four module mainframe version capable of up to 400 W of output power. Also available are a one and two module mainframe version with output capability of 100 to 200 W, respectively.

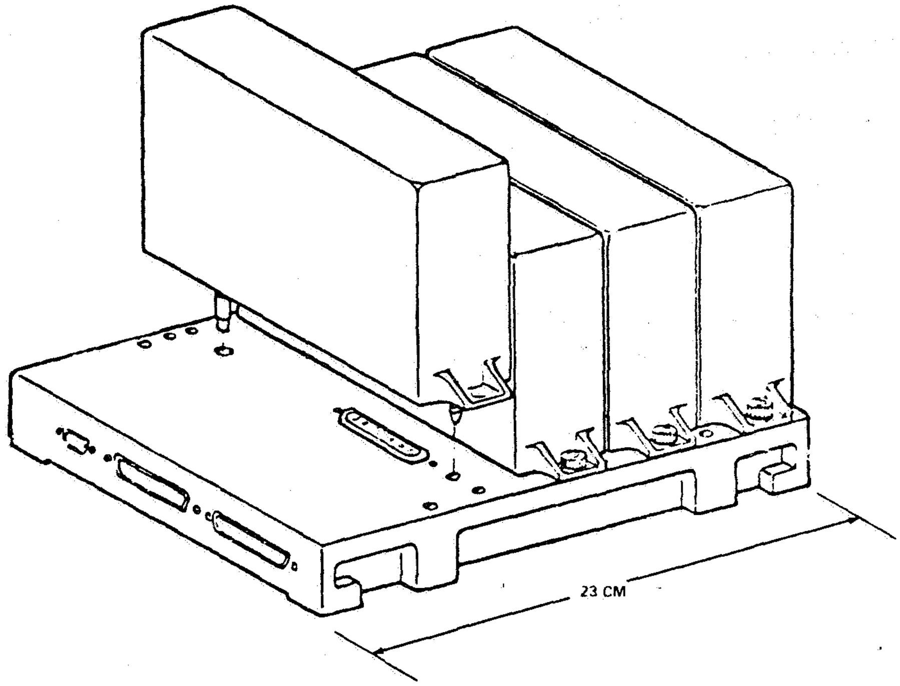

Figure 2. Load Center Converter (LCC).

A simplified functional block diagram of the LCC electrical design is in Figure 3. All output regulator modules are identical with the exception of the power transformer and a resistor divider network in the comparator and failure detection circuitry. These particular components are selected as a function of the output voltage level required.

Characteristics/Features

Figure 4 lists some of the more important characteristics and features of the LCC. Of notable significance is the overall LCC efficiency, 85 percent. This compares to 50 percent for nonswitched mode multiple-output converters and 60 to 70 percent for typical switched mode multiple-output converters. This is achieved by a single regulation stage and could be quite significant in terms of energy saving in a time of an energy shortage; particularly if all ground type power supplies would operate this efficiently.

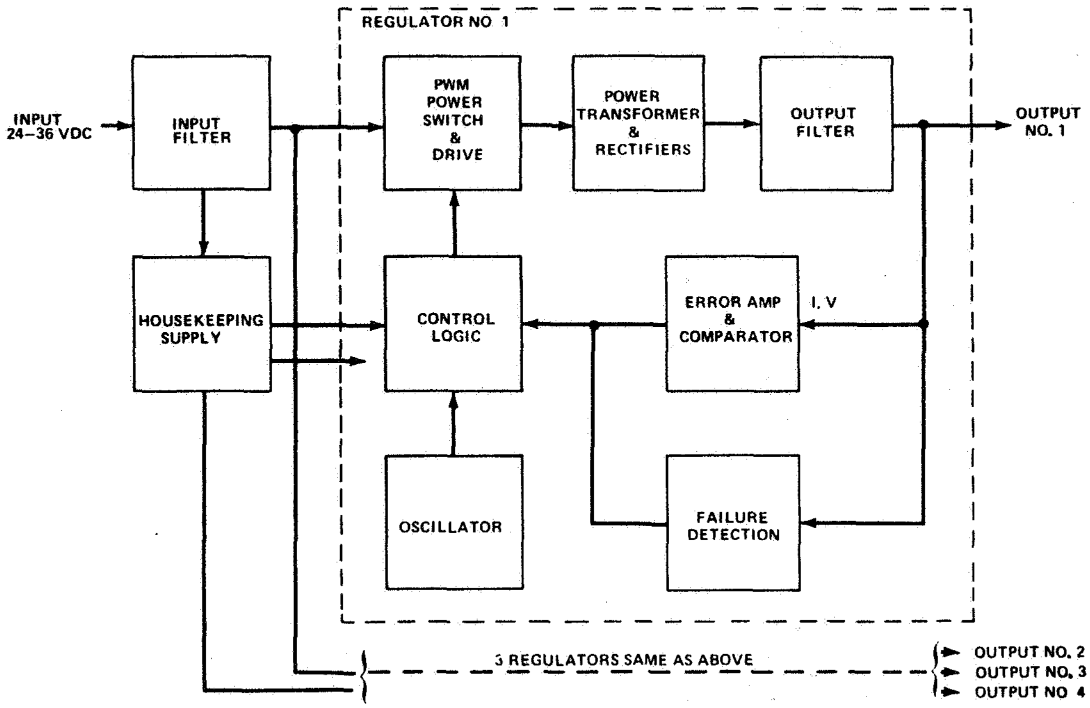

Figure 3. LCC block diagram.

CHARACTERISTICS

- INPUT VOLTAGE: 24 TO 36 Vdc
- OUTPUT VOLTAGE: 1 TO 4 DISCRETE VOLTAGE LEVELS (4 TO 80 Vdc)
- OUTPUT POWER: 100 TO 400 W SELECTABLE
- EFFICIENCY: 85 PERCENT MINIMUM WORST CASE AT FULL LOAD
- VOLTAGE REGULATION: ±0.25 PERCENT
- OUTPUT RIPPLE: 1.0 PERCENT MAXIMUM PEAK-TO-PEAK
- DIMENSIONS: LENGTH – 23.0 cm WIDTH – 21.3 cm HEIGHT – 13.7 cm
- WEIGHT: 6.4 kg

FEATURES

- REMOTE START-UP/SHUTDOWN CAPABILITY
- OVER-VOLTAGE/UNDER-VOLTAGE PROTECTION
- SHORT CIRCUIT PROTECTION
- INPUT/OUTPUT ISOLATION
- REMOTE SENSING CAPABILITY

Figure 4. Characteristics and features of the LCC.

HEAT PIPE

Heat Pipe Characteristics

The heat pipe selected for the LCC application is constructed of stainless steel tubing containing a stainless steel wicking structure and methanol as the working fluid (Fig. 5). This selection was based on meeting the LCC operational temperature requirements and the thermal transport requirement.

• ENVELOPE/WICK MATERIAL	STAINLESS STEEL
• WORKING FLUID	METHANOL
• THERMAL TRANSPORT CAPACITY	25 W
• THERMAL RESISTANCE	0.55° C/W
• THERMAL RESPONSE	50 s
• OPERATING TEMPERATURE RANGE	-40°C TO +120°C
• DIMENSIONS	13.2 cm X 0.64 cm
• WEIGHT	11 gm

Figure 5. Heat pipe characteristics.

Basic Heat Pipe Structure

The basic heat pipe structure consists of a sealed tubular container enclosing a wick structure for capillary flow of the liquid added to saturate the wick (Fig. 6). With the application of heat, some liquid vaporizes and flows to a cooler region where it condenses. The wick returns the condensate through capillary pumping action. Evaporation, condensation, and pumping of the liquid in a capillary wick are used to continuously transfer latent heat of vaporization from one region to another without external aids.

Transistor-Diode/Heat Pipe Interface

In employing heat pipes, careful attention must be given to obtaining a low thermal impedance at the heat pipe interfaces. For the LCC application, a saddle arrangement was devised for effecting a low thermal impedance between the power transistor cases and the heat pipe and a similar scheme was used for coupling the power diodes. These are the major LCC heat producing components. This technique resulted in a 14°C (25°F) reduction in hot spot temperature

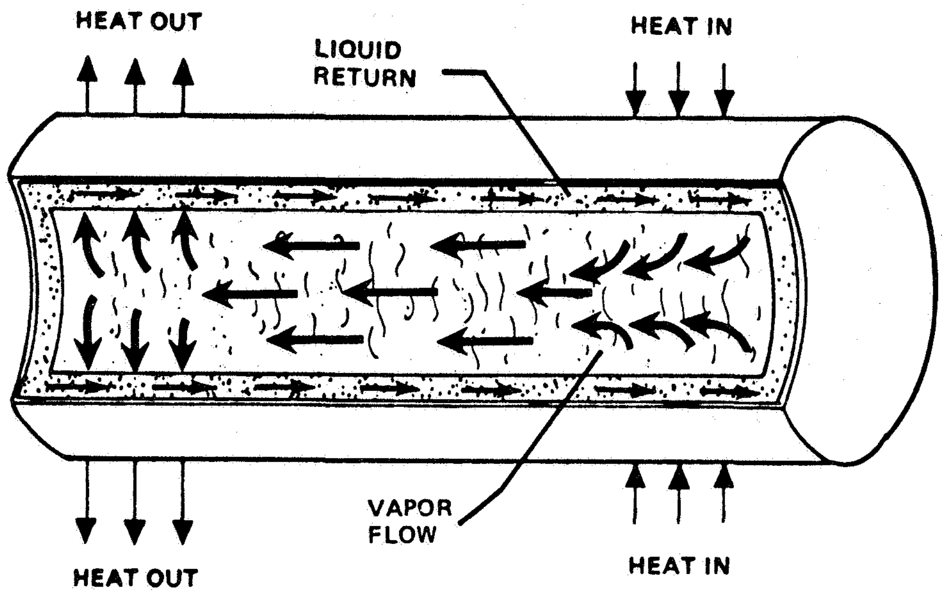

Figure 6. Basic heat pipe structure.

within the LCC. This can be translated directly into reliability — increased life of the components. In addition the basic technique is very applicable to ground-based systems which have high component densities and waste heat to be removed, and could result in significant simplifications and cost savings in heat removal systems. A diagram of the transistor-diode/heat pipe interface is shown in Figure 7.

SUMMARY

The LCC concept could find wind application in large computer and data handling systems or any type electronic system which requires one or more low level dc voltages. The piece part and housing commonality will reduce cost via large quantity buys and reduced number of spares. The heat removal concept employed in the LCC has resulted in reduced weight and volume, as well as simplified heat removal and reduced raw materials. The minimum 85 percent efficiency will also reduce operating cost substantially over presently used converters. The overall results — reduced energy use, simplified heat removal, reduced component temperatures, and a related increased component life, contribute significantly to today's needs. A summary of the LCC concept is shown in Figure 8.

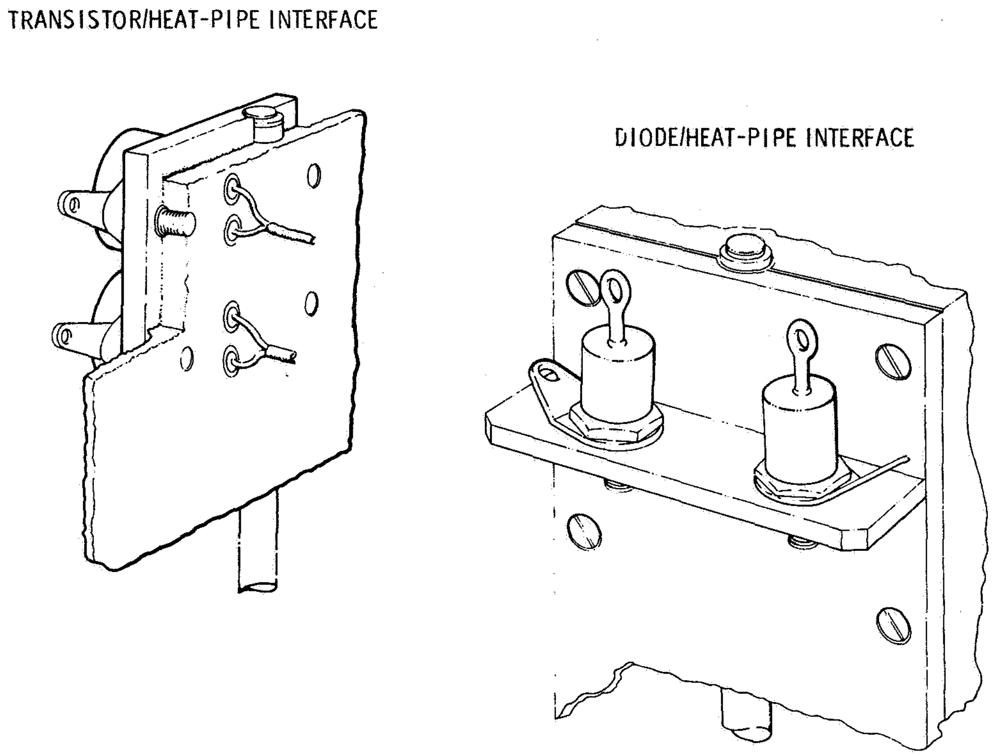

Figure 7. Transistor-diode/heat pipe interface.

- VERSATILITY
  - OUTPUT VOLTAGE SELECTABLE (4 TO 80 Vdc)
  - MODULAR
  - INTERCHANGEABLE
  - MAIN FRAME SELECTABLE (100, 200, 400 W)
  - PIECE PART AND HOUSING COMMONALITY
- HEAT REMOVAL
  - REDUCED WEIGHT – 40 PERCENT
  - REDUCED VOLUME – 24 PERCENT
  - REDUCED RAW MATERIALS
  - SIMPLIFIED HEAT REJECTION SYSTEMS
- ENERGY SAVINGS
  - COMPARED TO <50 PERCENT NONSWITCH MODE CONVERTERS
  - COMPARED TO 60 TO 70 PERCENT TYPICAL SWITCHED MODE CONVERTERS

Figure 8. Summary.