Low Temperature Data Acquisition Controller and Computer

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ABSTRACT

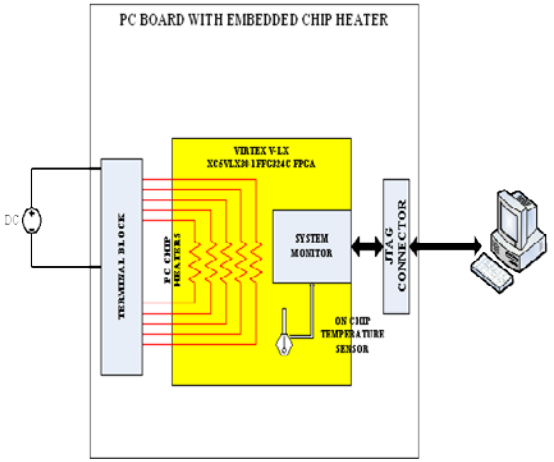
- Many of NASA's future missions to outer planets will require computers and data collection electronics to endure very low temperatures.
- Current state-of-the-art technology is to use heating elements in a protective box (warm-box). This approach results in elaborate wiring, adding to mass and power and creating complex testing fixture.
- Our innovation is to use embedded board heaters that consume limited amount of power.
- This technology along with the radiation tolerant and hardened FPGA technology enables us to build data acquisition controllers and computers that can operateat cryogenic temperatures.
- New FPGA features such as built-in temperature sensors and system monitors are used to automate the heating control.

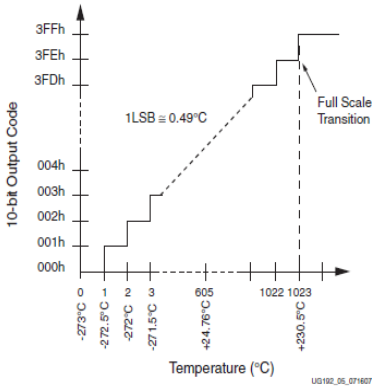
BACKGROUND

- JPL/CALTECH testing results
- ACTEL A54SX32A-CQFP208 and XILINX VIRTEX and VIRTEX II PRO FPGA (XCVR600-CQFP228 and XC2VP20-FF1152) can function in cold temperatures down to -165 °C.
- ACTEL and VIRTEX (XCVR600) were tested using custom-designed PC boards while XILINX VIRTEX II PRO (XC2VP2) used COTS board. Voltage regulators were bypassed and RESET circuit was modified.
- XILINX VIRTEX and ACTEL FPGA were functional down to -165 °C and XILINX VIRTEX II PRO was functional down to -120 °C.
- XILINX VIRTEX FPGA showed a large surge current in its core supply at cold temperature during configuration.

BAENG WORK

- Embedded PC board heaters tested with XILINX VIRTEX V
- VIRTEX V system monitor is used for temperature monitoring
- FPGA configured thru JTAG interface using IMPACT andChip Scope PRO.
- FPGA ADC/Temperature transfer function can theoretically operate down to -273 °C.
- Objective is to maintain die temperature at -55 °C

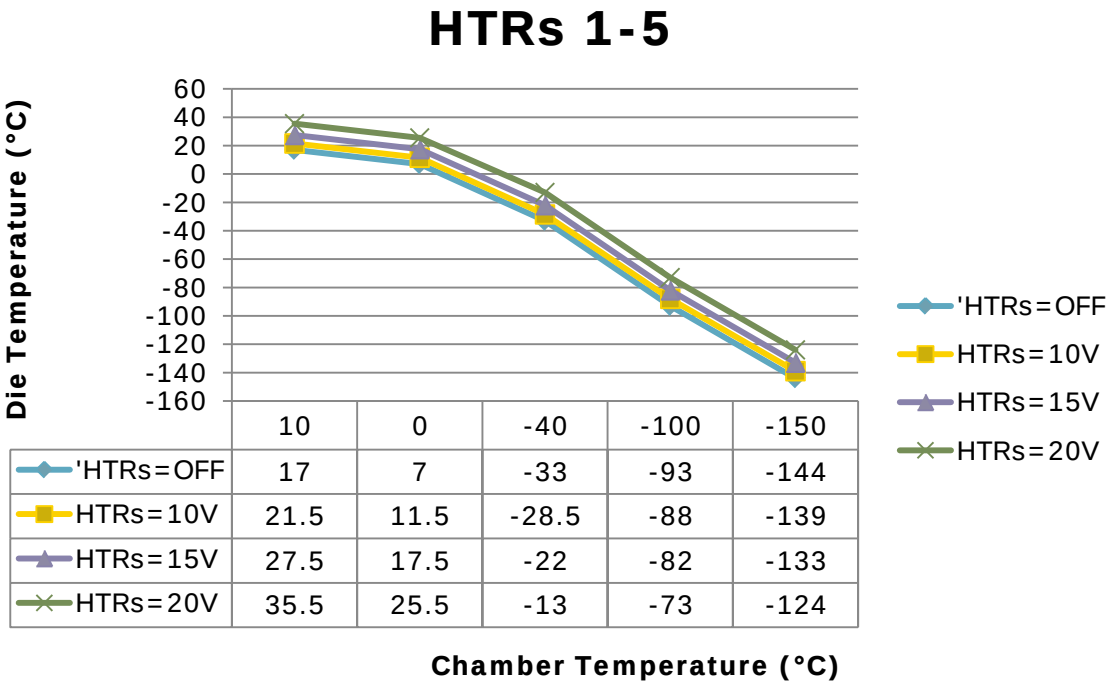




CRYOGENIC TESTING RESULTS/1

- Testing was done from room ambient temperature down to – 150 °C starting with 10, and continuing to 0, -40, -100, -150 °C. FPGA was re-configured thru JTAG interface during each temperature decrements.
- FPGA internal die temperature was taken for various heater configurations. Heaters which are located beneath the FPGA internal die had the most effect on the die temperature.
- Heat transfer was mainly thru conduction at PC board to FPGA via BGA pins.
- Air between the PC board and underneath of the FPGA mostly worked as an insulator.

CRYOGENIC TESTING RESULTS/2



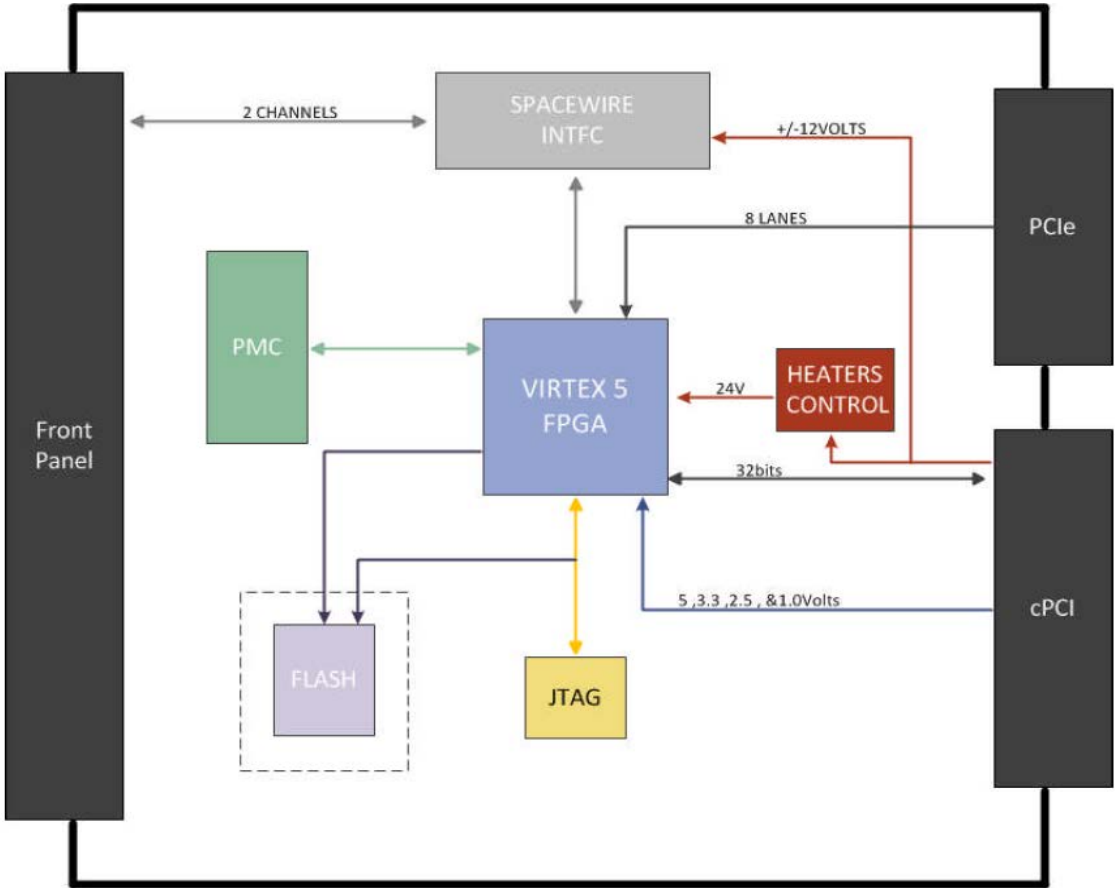
	10	0	-40	-100	-150
'HTRs=OFF	17	7	-33	-93	-144
HTRs=10V	21.5	11.5	-28.5	-88	-139
HTRs=15V	27.5	17.5	-22	-82	-133
HTRs=20V	35.5	25.5	-13	-73	-124

	Current(mA)	Power (W)
Heaters=OFF	0	0.00
Heaters=10V	41.3	0.41
Heaters=15V	61.9	0.93
Heaters=20V	82.6	1.65

HEAT TRANSFER EFFICIENCY STUDY

- Thermal simulation shows that die temperature can be increased two fold with the heaters in vacuum. Theoretically die temperature can be raised to -100 °C at -150 °C ambient
- Covering the FPGA with shiny insulated material causes less heater radiation loss and higher die temperature. Lab test showed about 5 °C improvement at room temperature.
- Heating element study is under way to design more efficient heaters.
- Further improvement will be by filling the gap between the PC board and FPGA with epoxy filler material that is thermally conductive and electrically insulating.
- Manufacturing studies are under way.

CRYOGENIC DATA ACQUISITON AND CONTROLLER BOARD



Summary and Conclusions

- Cryogenic testing results show that it is possible to increase the die temperature of the FPGA by using embedded heaters. Further studies are needed to increase the efficiency of the heaters and in turn reduce the power consumption.

- Goal is to keep the die temperature of the IC at -55 °C.