MICROCOMPUTER BOARDS FOR SAFETY CRITICAL SYSTEMS OF NUCLEAR POWER PLANTS AND OTHER HIGH RELIABILITY INDUSTRIAL APPLICATIONS

Reactor Control Division
B. Ganaraj
Fuel Handling Control Section
Umesh Chandra
Assoc. Director, Automation & Manufacturing Group
and
P. Sudhakar
Electronics Corporation of India Limited

Introduction

Microcomputers found wide application in many embedded Control and Instrumentation (C&I) systems starting in early eighties. However, its use in safety critical systems of Indian Nuclear Power Plants (NPP) was restricted till last few years, one of the main reasons being non-availability of robust designs with built-in fault diagnostic and safety features. Internationally available microcomputer boards did not have these desirable features. Hence, a family of (Intel/Motel based) microcomputer boards on a proprietary bus called 'EURO bus', along with signal conditioning and power supply boards was developed in Reactor Control Division. These development efforts ensured self-reliance on delivering reliable computer based safety critical systems of NPP and other high reliability industrial systems.

These boards have been used in safety critical systems like Programmable Digital Comparator System (PDCS), Reactor Regulating System (RRS) and Process Control System (PCS) in KAIGA-1,2 and RAPP-3,4. In Fuel Handling Control System (FHCS) of Kaiga-1,2 and RAPP-3,4, X-ray diffractometer system, TG vibration monitoring system and Laser tuning system, boards from this family have been used. These boards have also replaced foreign designs in some C&I systems at NFC. Recently, a prototype multi-nodal RRS for 500 MWe has been integrated using these boards. Upgradation of some C&I systems of Dhruva and Apsara is planned using these boards. PDCS, RRS, PCS and FHCS of KAIGA-3,4 will also be made using these boards. These microcomputer boards have been used in above systems in different configurations like single computer, Dual processor hot standby, Triple modular redundancy and Multi-processor. More than 3500 boards of this family are already in use in various C&I systems.

This board family has about 40 different types of boards needed for various C&I applications. The board designs are NPC QA qualified. The boards have double EURO format (233.34 mm x 160 mm). These boards have been manufactured and supplied by ECIL for the above listed applications and are available from them as standard products.
List of main function modules

1. Main processor module with maths co-processor
2. Expandable memory module
3. Isolated digital input module with finite impulse testing
4. Isolated digital output module with read back
5. Relay output module with read back
6. Multi-channel 12 bit ADC module with on board calibration and MUX fault detection
7. Multi-channel 16 bit ADC module with on board calibration and MUX fault detection
8. Isolated 4-20 mA current output module with facility to read back
9. 2 wire, 3 wire signal conditioning modules with isolation for mV, RTD and current inputs
10. Supply monitoring, NMI manager and battery backed RAM module
11. Watch dog timer module
12. Intelligent communication module with isolated MODEM, DMA and DPRAM
13. Expandable serial communication interface module
14. Redundant network interface & controller module
15. Dual processor arbitrator module
16. Bus extender master module
17. Bus extender slave module
18. Multi-channel DMA interface module
19. Expandable interrupt controller module
20. Parallel processing DSP module
21. Software task monitor module
22. Floppy disk interface module
23. IDE interface module
24. Alpha Numeric Key board interface module
25. Alpha Numeric Display controller module & Display module
26. Low and High inertial mini micro stepper modules
27. Pulse width discriminator isolator with pulse counter module
28. Proportional controller module for stepper motor
29. Servo amplifier for valve solenoid controller module
30. Various digital and analog back plane modules

Micro-processor, coprocessors & support chips

The processor architecture and timings are important issues while selecting a microprocessor. Familiarity and easy availability of microprocessor is also an important consideration. For real-time systems, assembly language know-how is essential to get optimized and reliable software code and hence the instruction code of microprocessor should be simple.

System bandwidths required for various C&I applications were studied and 2 to 4 Mbits/sec data BW was found to be more
than sufficient. Higher end microprocessors like 80286, 80386, 80486 were also considered but were found to be overkill. For C&I applications, 16 bit data bus and 20 bit address bus was found to be sufficient. Intel 8086 microprocessor was therefore chosen with its powerful co-processor set and support chips for its familiarity simplicity and availability. Thus the designs of these boards are based on Intel series and few motel series chips. Choosing a simple microprocessor (8086) and distributing the peripheral jobs to specialized co-processors (8088, 80186, 8751 8087, 82586, ADSP2100) and support chips gave elegant, reliable and robust design with desired throughput for various C&I systems of NPP. Moreover these Intel series ICs are generic in nature and are available from multiple sources.

Euro Bus: with 8086 natural signals

An extension of natural signals of chosen microprocessor in desired form factor gives a reliable bus. The designers of reliable embedded systems like Siemens, ABB and Triconix also follow this criterion. System designers who have selected Signetics 2670 or Texas TMS 32XX micro-processors have used natural signals of their selected microprocessor and thus have their own proprietary bus with proper form factor. This practice also saves component counts and reduces timing errors thus giving elegant, simple and reliable design.

Having chosen the main microprocessor and powerful co-processor/slave processor, next step was to design boards on a suitable bus. Proprietary bus signals were selected with 96 pin Euro connector. Rows A and C were dedicated for basic maximum-mode 8086 signals, along with power inputs. Row B was used for serial and parallel arbitration signals, for multi-master expansion. This allocation of signals resulted in design of most of the boards in double layer instead of multi-layer thus saving bare PCB cost. The 'EURO bus' thus has following bus signals: address signals A0-A19, data signals D0-D15, control signals INT1-INT4, INTA, HOLD, HLDA, SYSALIVE, LOCK, BHE, NMI, MEMRD, MEMWR, IORD, IOWR, RESET, CLK, XACK, in A and C rows of EURO connector and multi-master signals ARB CLK, BPRN (1-4), BPRO (1-4) in B row of EURO connector. A single bus structure was chosen for all the boards including I/O boards.

Features of EURO bus :

- Full capability of 8086 and other co-processors utilized.
- All Intel/Motel processors and co-processors interfaced directly.
- Single type bus structure to enhance reliability.
- Swappability of any board anywhere in a bin or any other extended bus bin.
- Expansion of bus DMA for multiple DMA channels
- Expansion of bus interrupts upto 32.
- Any board can be configured in memory or I/O map with all memory & I/O address available without gaps.
- Board absence detection facility.
- Power fail management to gracefully shutdown the node.
- Detection of absence of board (s) can be used to reconfigure the system.
- Multi-master expansion up to four processors.
- On bus failure, or any software or hardware failure, the outputs can be taken to desired safe state.

Microcomputer boards

- Board designs are based on generic components. Long term availability of components is thus assured from multiple sources.
- Generic component pin compatibility gives flexibility to use MIL or commercial components in same layout.
- All components are de-rated to 50%.
- The logic design is open and not programmed or hidden into PAL, EPLD and FPGA. Due to this bit flow and signals can be easily traced for verification. Servicing and
repairing with generic components is easy and does not require any programming by site staff.

- On-line fault detection in hardware is possible to a large extent.
- Boards removal and insertion while system is running can be detected. Depending on application, the system can be reconfigured or can be gracefully shut down.
- Bus extension to other bins up to 10 feet distance is possible for large I/O applications.
- Fail-safe features are provided either to freeze or force the outputs to any desired value.
- The field connections are provided through IDC connectors on backplane, which is a desirable feature for easy maintenance.
- All boards conform to PP-E-1443 of NPCIL.

**Power supply boards**

For safety critical systems, reliable power supplies are needed. Power supply boards were designed in Reactor Control Division to get reliable and robust power supplies with hot plugging and load sharing features. These power supply boards are based on current mode controllers and have desired controller stability margins. These power supplies have been used in various C&I systems of Kaiga-1,2 and RAPP-3,4 and are now available from ECIL as standard products.

**Conclusions**

A family of microcomputer boards with high reliability and on-line diagnostic features has been developed. The family of boards covers all possible functions needed in a C&I system. These boards have found wide use in NPP and other critical jobs.