# ARM BASED EMBEDDED EPICS CONTROLLER

FOR

# BEAM DIAGNOSTICS IN CYCLOTRONS AT VECC

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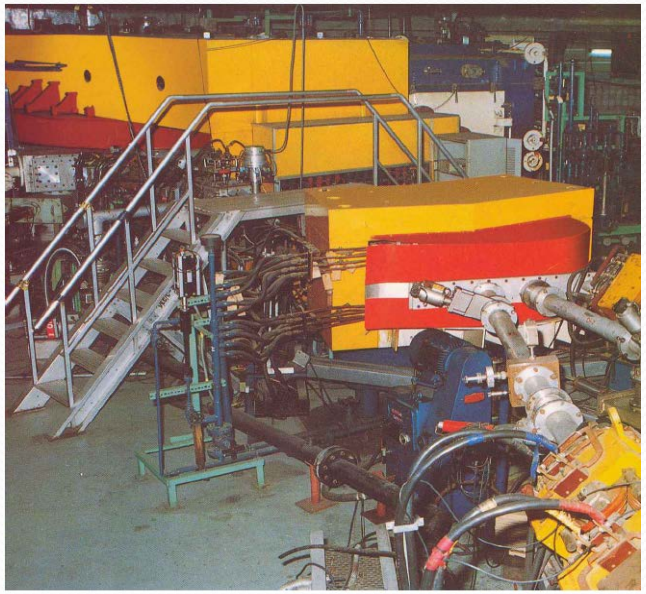



## K-130 Room Temp. Cyclotron

- Pole Diameter : 224 cm
- Average Field : 17.1 kG
- Conductor : NbTi in Cu
- Ion Source : PIG & ECR
- Beam Energy : 25-130 MeV
  (Proton, Alpha and Heavy Ions)

## K-500 Superconducting Cyclotron

- Pole Diameter : 142 cm
- Average Field : 49 kG
- Conductor : NbTi in Cu
- Ion Source : ECR
- Beam Energy : 80MeV/nucl

# Subsystems :

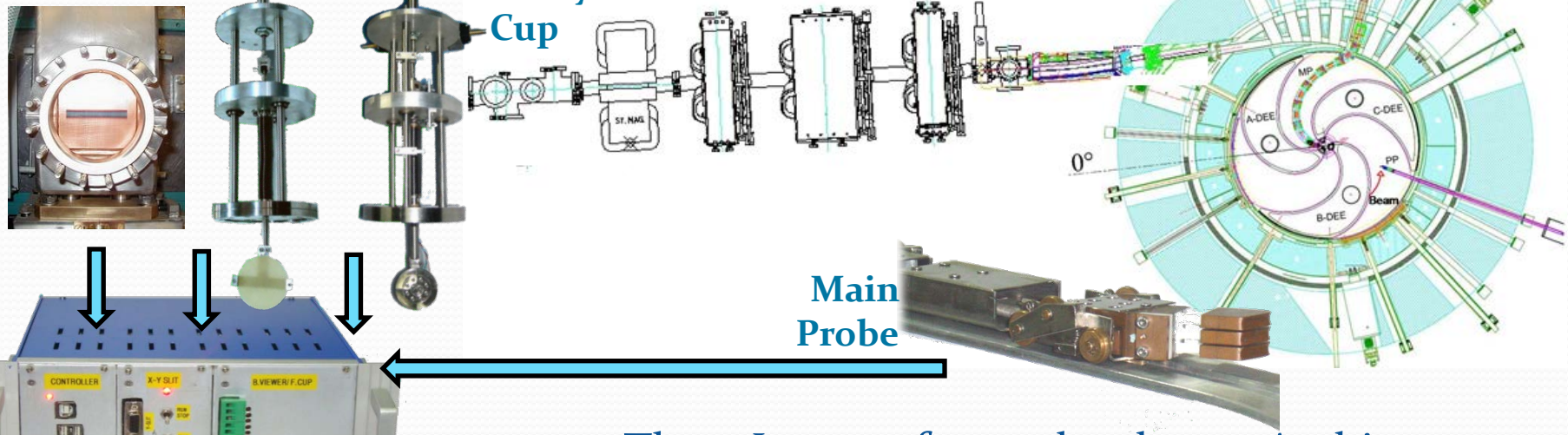
- High Current Power Supplies
  - Main Magnet, Trim Coils, Beam-line magnets
- Radio Frequency System
  - Freq. Range : 9-28 MHz (for SCC), 6-15 MHz (for VEC)
- Vacuum System
  - Working Pressure : $10^{-7}$ Torr
- ECR Ion Source
  - External ECR, Axial injection
- Beam Diagnostic System
  - All the beam regions

# Beam Diagnostics : Components

- Axial injection line
  - Faraday cups, X-Y Slits etc.
- Acceleration region
  - Main probe, Delta probe and Beam viewer (Borescope) probe
- Extraction region
  - Magnetic channels, Deflectors position, Viewer probe etc.
- External beam line
  - Faraday cups, X-Y Slits, Beam viewers etc.

# EPICS Control Architecture

## (in Beam Diagnostics Control System)




- Three Layer software-hardware Architecture
- Distributed Control System
- Modular Beam Diagnostics Crate
- EPICS IOC on Central Communication Controller Card.

# Beam Diagnostics Crate

- Pluggable modules :
    1. ARM based Master controller card
    2. Stepper Motor module
    3. X-Y Slit module
    4. Encoder Read-Out Module
    5. Relay Module
    6. I/O Module

- RS-232 communication with Hardware Modules

- Maximum of 8 pluggable modules can be placed in the crate other than master controller

- Dedicated Serial Line from Master Controller to each Hardware Module

# Why Embedded Systems

## Instead of Traditional PC ??

- Cost effective
- Small Size
- Flexibility of designing EPICS embedded control hardware or instrumentation
- Easy Plug-in for customization
- Easy Maintainability

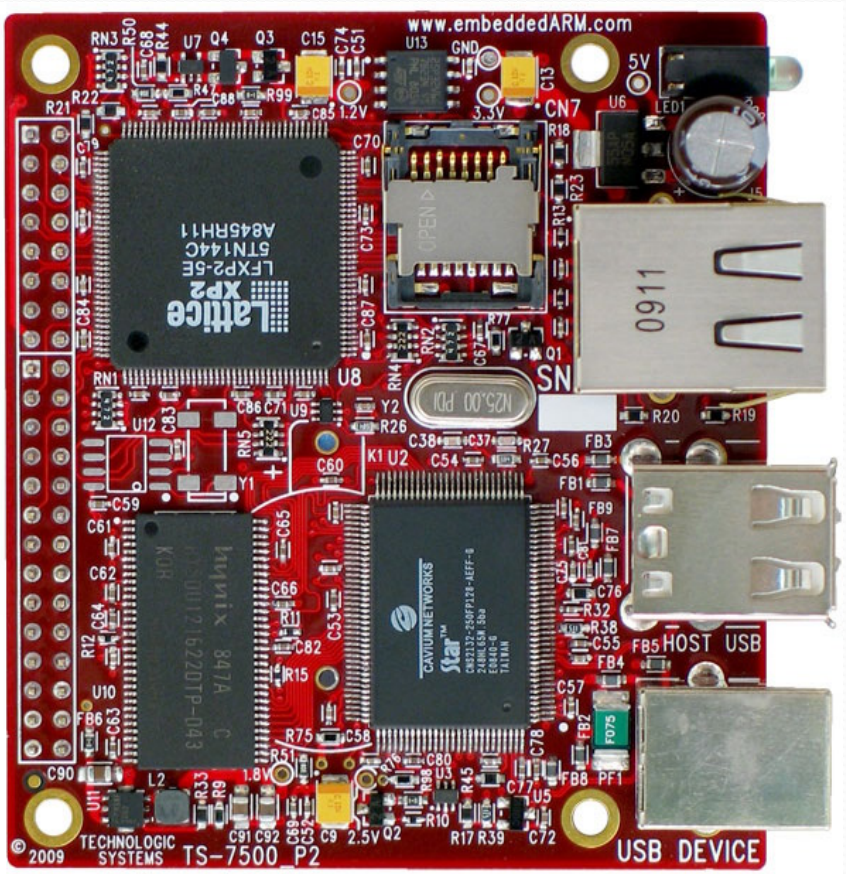
# Why ARM (Advanced RISC Machine) ??

- Industry standard embedded microprocessor architecture. (95% of the smartphone mobile industry)
- Low power consumption
- Smaller Footprint
- Low Cost
- Soft IP cores
- Peripheral Integration
- License to multiple manufacturers – Obsolescence mitigation
- Compatibility with Linux OS and GNU gcc compiler support

# ARM processor

- 32 bit RISC processor.
- High Code density.
- Hardware Debug Technology.
- Load store architecture.
- 7 CPU Modes : Six privileged modes and one non-privileged mode.
- Inline barrel shifter.
- Thumb 16 bit instruction set.
- Conditional execution : An instruction is only executed when a specific condition has been satisfied.
- 3 to 8 stage pipelining architecture

# TS7500 Board: Heart of diagnostic instruments




| Item | | TS-7500 |
|---|---|---|
| **CPU** | | ARM922T (250Mhz), From Cavium Networks |
| **OS** | | Linux 2.6.24 (Debian) |
| **Memory** | DDR RAM | 64 MB |
| | SRAM | 512 KB |
| | Flash ROM | 4 MB |
| | External SD Card | 2 GB |
| **Peripherals** | DIO | 33 Pin DIO |
| | USB 2.0 | 2 (Host) and 1 (Slave) |
| | Ethernet | 10/100 Mbit |
| | UART | 1 TTL serial console port and 8 XUART TTL serial ports. |
| **Power** | Low Power | 400mA @ 5V |

# EPICS Performance Analysis on TS-7500 for Beam diagnostics

Preparation:

Three hardware modules for beam-viewer, faraday-cup and slit-control require

1. 4 asynchronous analog input (ai) with 10 Hz scan rate with real hardware
2. 5 asynchronous analog output (ao) with 10 Hz scan rate with real hardware
3. 16 calculation record (calc) with 10 Hz scan rate

# EPICS Performance Analysis on TS-7500 for Beam diagnostics

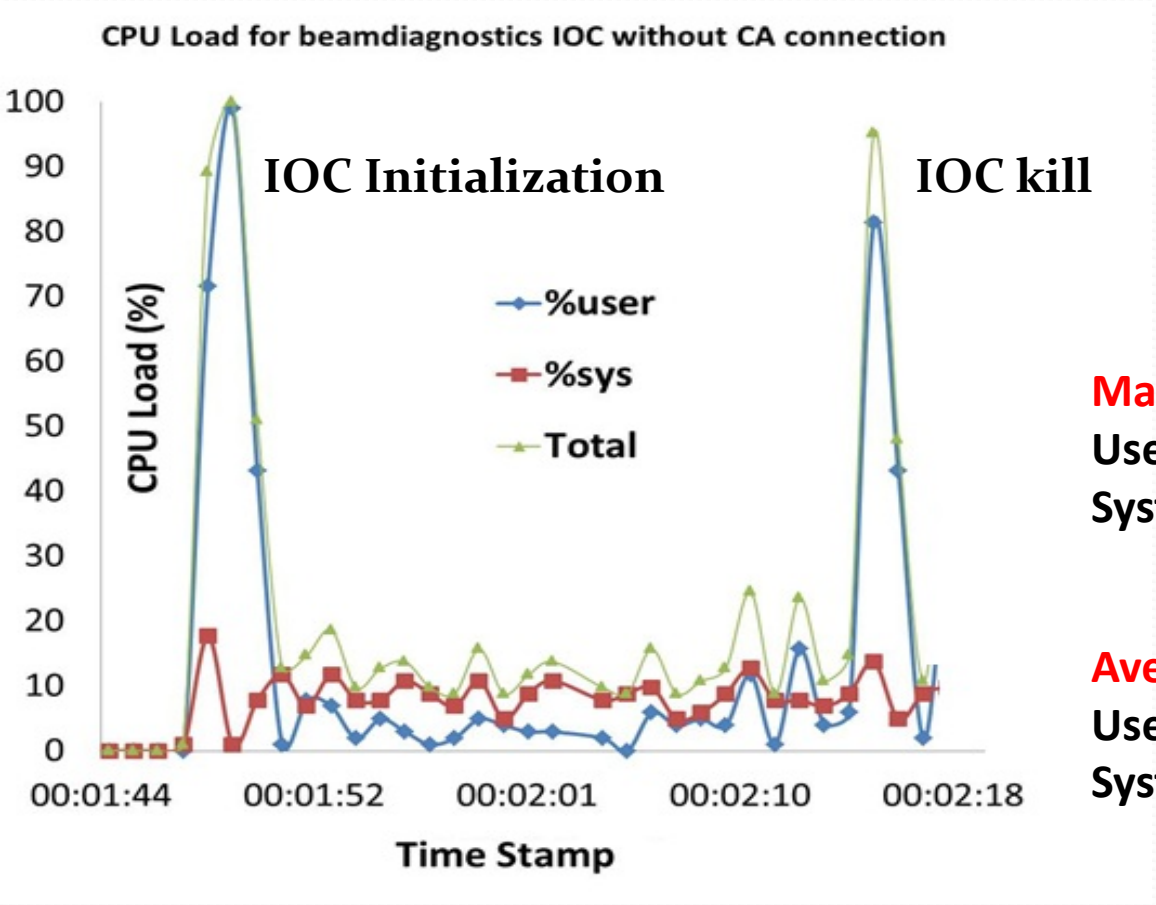
Preparation:

- Device driver is written using asyn module
- SYSSTAT tool is loaded in TS-7500 and run
- IOC is loaded in TS-7500 and run

Objective is to identify CPU load for record processing and asynchronous callback routine

# EPICS Performance Analysis on TS-7500

## for Beam diagnostics




**Maximum CPU Load :**
**User: 15.69%**
**System: 12.75%**

**Average CPU Load:**
**User: 4.43%**
**System: 8.60%**

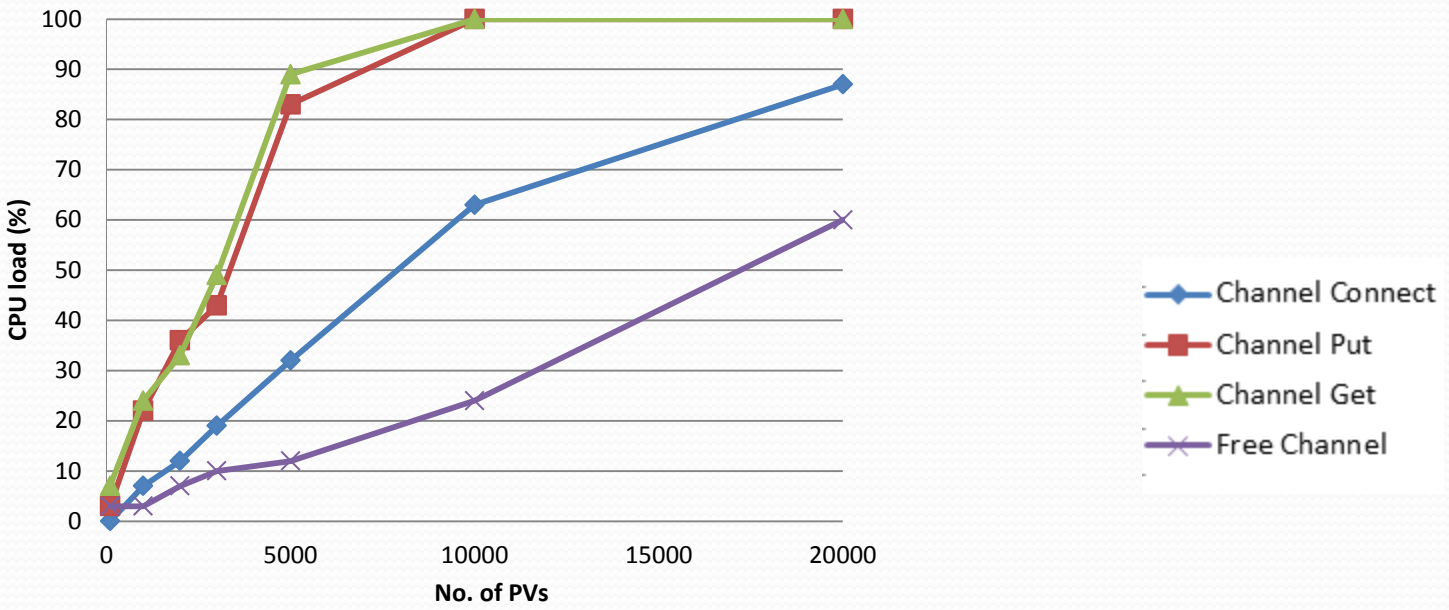
# EPICS Performance Analysis on TS-7500 for Beam diagnostics

**As the rest of the CPU time can be utilized for CA requests, maximum get() and put() possible on TS-7500 is measured**

Preparation:

1. CaServer Application is run on TS-7500.
2. Modified ca-time tool is used from an x-86 client connected in LAN.
3. Server CPU Load (on TS7500) is calculated for individual Channel Access event: CAget ,CAput , CAconnect and Cafree.
4. Results are studied with increasing number of client requests

# EPICS Performance Analysis on TS-7500

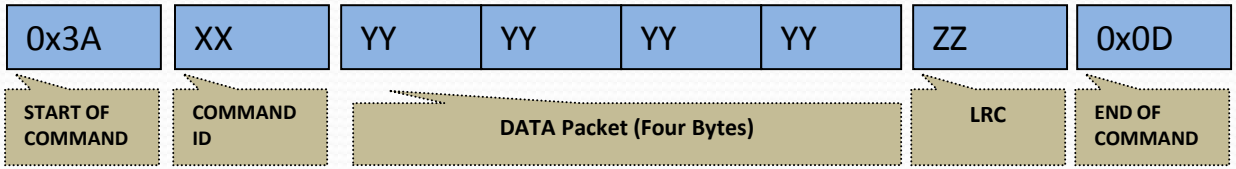



**% utilization of CPU vs No. of PVs**

- **CPU utilization exceeds 80% for 5000 Channel Get requests from client.**
- **As the number of PVs in our Beam diagnostics system is much less, it will not overburden the CPU.**

# Details about developing ARM based Embedded controller:

1. Device-driver is developed using asyn
2. The serial communication protocol for the module is




3. All required EPICS record sets for beam diagnostics reside locally
4. Deadlock conditions, if any, are checked and avoided in db

Following tasks are performed after the above steps

- Porting EPICS IOC on ARM board
- Developing a GUI for the Operator Interface

# Porting of EPICS on ARM processor

1. Installing Cross Compiler toolchain

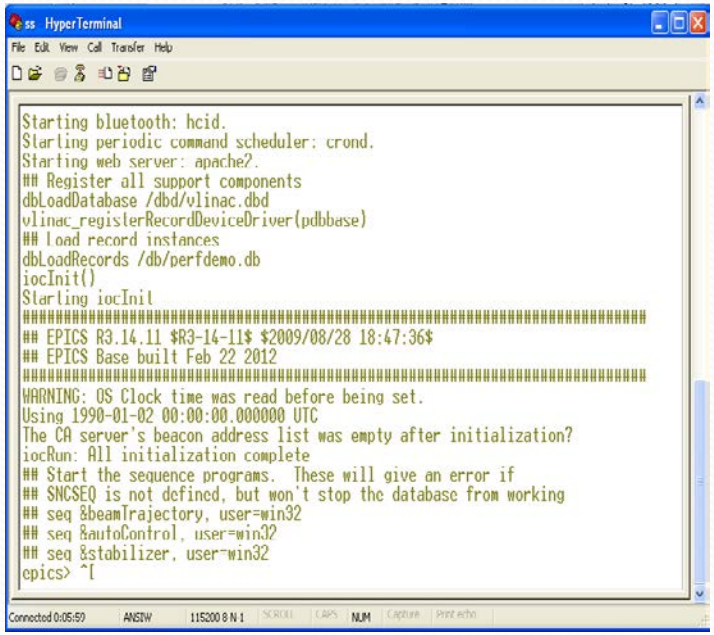
   arm-linux-gcc toolchain available from GNU

2. Target configuration

   CROSS_COMPILER_TARGET_ARCHS =linux-arm

   GNU_DIR = /local/anj/cross-arm/gcc-3.4.5-glibc-2.3.6/arm-linux

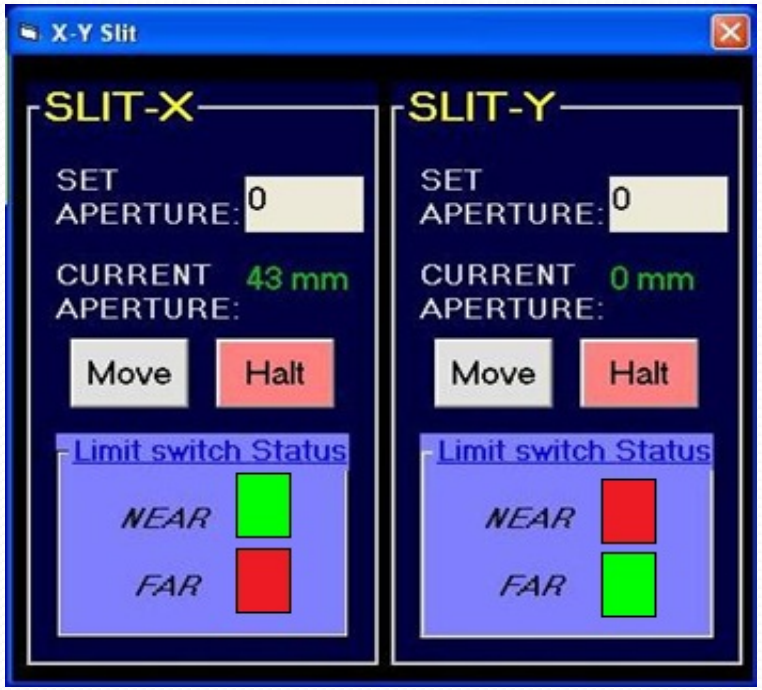
3. Build EPICS base
4. Copy to Target Board (TS7500)




Hyperterminal window showing the serial console terminal of ARM board with EPICS running on it.

# GUI for Operator Interface

- Microsoft Visual Basic (VB) is chosen as the OPI developmental platform.
- Indeginiously developed CA embedded Active-X components e.g. *CA Text, CA Image, CA Setpoint* and *CA button* are used.
- Easy Channel Access (EZCA) library used for CA functions .
- Advantages:
  - Easy configuration i.e. pvName and init() call
  - Drag & drop type reusable component
  - Rich GUI library
  - Less complicated coding style
  - Expertise in configuration of X-server (e.g. *Exceed*, *Xming*, Cygwin/*X*) not required




GUI for interfacing Slit Controller used in Beam Diagnostics application developed using VB

# Experience during actual operation

- The SD-card of the board was frequently damaged
- Maintenance became a challenge
- The  reason was identified and found radiation is the possible reason
- Field cables are extended and the instrument were kept far away
- Problems appeared to be solved, however, initiative is being undertaken to replace the SD card and make the embedded system a diskless device with remote disks.

# Conclusion

- In this project we have successfully ported EPICS IOC on ARM9 processor.
- EPICS based ARM controller card has been designed and tested for beam diagnostics subsystem of Cyclotron at VECC.
- CPU load to run EPICS on TS-7500 was performed and found satisfactory

# Future scope:

- Instead of ARM Single Board Computer we have also targeted FPGA with soft / hard embedded processor cores.
- This will integrate the IOC and digital control hardware within a single FPGA, thus reducing the overall hardware complexities of field devices.
- Xilinx FPGA supports MicroBlaze soft core processor and Dual Core ARM Cortex A9 hard processor.

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