BEAMLINE SUPERVISORY SYSTEM USING A LOW-COST SINGLE-BOARD COMPUTER

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Abstract

Sirius is the new accelerator facility, under construction at the LNLS (Brazilian National Synchrotron Light Laboratory) site, in Campinas, São Paulo. The new machine is a 3 GeV, low emittance storage ring designed to accommodate up to 40 experimental stations. During beamline operation, supervisory systems are an important tool to provide information about machine status and beamline operation modes for the beamline´s users. A modern TV based broadcast system was developed to meet this application, using low-cost single board computers with an interface to EPS/PPS system. The details about hardware, software configuration, user's requirements as well suggestions on further improvements, will be presented.

INTRODUCTION

At UVX, the current machine at LNLS, the machine status broadcasting system is based on antiquated cable television topology. Furthermore, beamline status is monitored only using audible sounds (at hutch armed status) and light indicators. This system has become obsolete and is no longer manageable, with an additional drawback regarding the support for people with color vision deficiency (such as Daltonism). A new and modern supervisory system is envisioned for Sirius, to provide readable warnings, useful information and customized sounds for beamline users.

A broadcast system, based on web browsers and LED TV´s is proposed. The system displays the machine status (such as storage ring current, beam lifetime, machine energy, top-up) and beamline operations modes (photon beam status: beam on, beam off, imminent beam, hutch armed, etc).

The supervisory system was developed using a low-cost single board computer, the Beaglebone Black [1], integrated with the Personnel Protection System (PPS) and Equipment Protection System (EPS), both based on industrial programmable logic controllers (PLCs). Beaglebone Black (see Figure 1) is a powerful low-cost single board computer equipped with a Sitara ARM Cortex-A8 processor running at 1 GHz. The board provides 512 MB of RAM, two 46-pin expansion connectors (with much general-purpose I/O pins), on-chip Ethernet, a microSD slot, a USB host port and HDMI video interface. The board also runs many distributions of embedded Linux providing support for a variety of programming languages.

By means of Python scripts and web browsers, the system was designed for low cost, high flexibility and expandability. This also allows for a efficient way to create fully customized warning messages for users.

BEAMLINE SUPERVISORY SYSTEM

System overview

During normal operation, the system provides machine status (storage ring parameters) using a web-based application. The operation group, based in the storage ring control room, can configure this information. Besides the storage ring information, the beamline´s users have the need to know the photon beam status, the beamline operation mode and any other information required for that specific experimental station, such as lasers, high pressure cells, robots, etc.

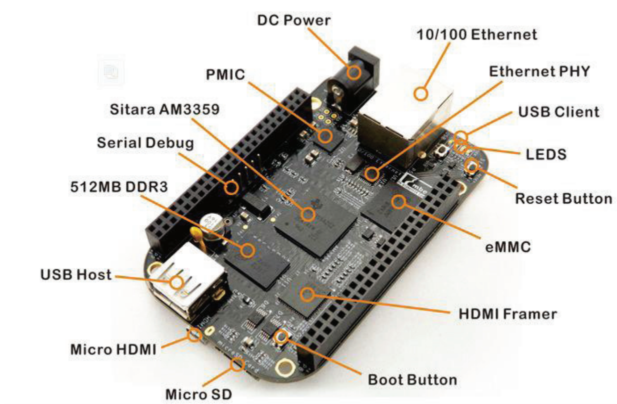

Figure 1: Beaglebone Black.

The beamline supervisory system flowchart is shown below (see Figure 2). The PPS is an engineered interlock system that monitors the various devices installed in the beamline, for personnel safety and provide emergency beam shutdown. PPS is based on PLC's that monitor the positions of the front-end shutters, beamline shutters and beamline hutch doors. This system also defines all the safety functions to avoid any accidental exposure to radiation inside the beamline hutch.

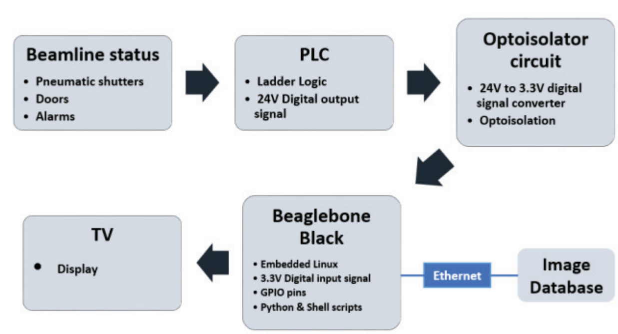

Figure 2: Supervisory system stages.

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Once the beamline mode is determined by each PPS, the PLC will send digital signals to the signal conditioner mezzanine board. The mezzanine board translates the 24V logic level from PLC to 3.3V LVTTL used by the Beaglebone board.

A total of 8 digital signals is provided by the PLC. One of these signals is used as an interruption or control signal, while the remaining 7 signals are used to identify the beamline status, as defined in the protocol identification software. Considering this range of signals, 128 status messages can be controlled by the Beaglebone board. Treatment of the received signals and image display is controlled by Python script using the Pygame package [2] and Adafruit Beaglebone IO Python library [3].

HARDWARE OVERVIEW

The Mezzanine Board

As previously mentioned, the standard voltage of PLC´s is 24V. The Beaglebone Black works with LVTTL levels (3.3V). In this sense, a logic translation circuit, using optocouplers, was designed (see Figure 3).

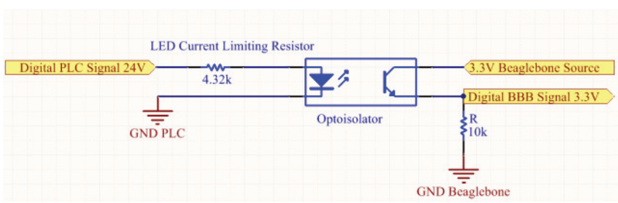

Figure 3: Opto-isolator circuit.

When the PLC's digital signal is at a high level, the photodiode is directly biased and makes the phototransistor transmit its collector signal (3.3V Beaglebone source) to the emitter (GPIO pin). Thus, it guarantees insulation of signals without the need for an additional external voltage source. The circuit receives the PLC ground reference and the 8 digital signals, which are reduced to 3.3V logic reference, are then transmitted to their respective GPIO pins.

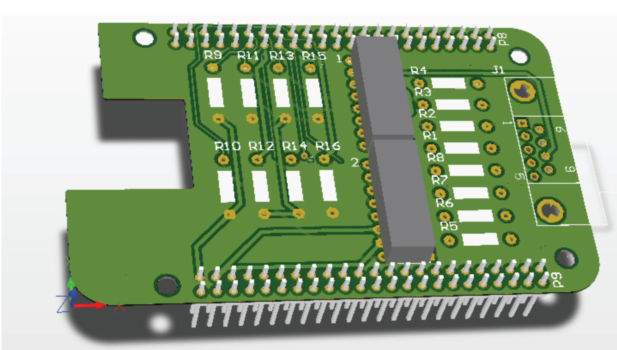

Figure 4: 3D view of the optocoupler circuit mezzanine board prototype.

The processing board interprets the signals received and shows the proper image with the relevant message, stored in a common directory on the internal network in which all boards are connected. The connection to the TV is performed using the available micro HDMI video output of the Beaglebone. The TV screen resolution of is not of relevance, since the software has been implemented to adapt to any resolution.

To accommodate the optocouplers circuits, a mezzanine board was designed (see Figure 4).

The Beaglebone standard mezzanine cards are called “capes”. The prototype board design was developed using Altium designer PCB software that provides schematic capture and Printed circuit board (PCB) design (see Figure 5).

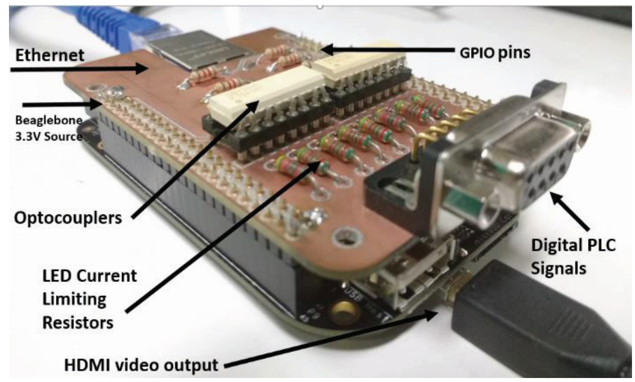

Figure 5: Prototype cape embedded in Beaglebone.

SOFTWARE OVERVIEW

Operating System and Software Configuration

When there is no change in the beamline status, Beaglebone shows the standard web page, displaying the storage ring information, on the screen (see Figure 6). The default web page provides information about the machine status such as beam energy (MeV), instant beam current (mA), electron beam lifetime (hours) and the status of all gamma shutters presented in the experimental stations. The electron beam of the current graph shows the trend of the last 15 hours.

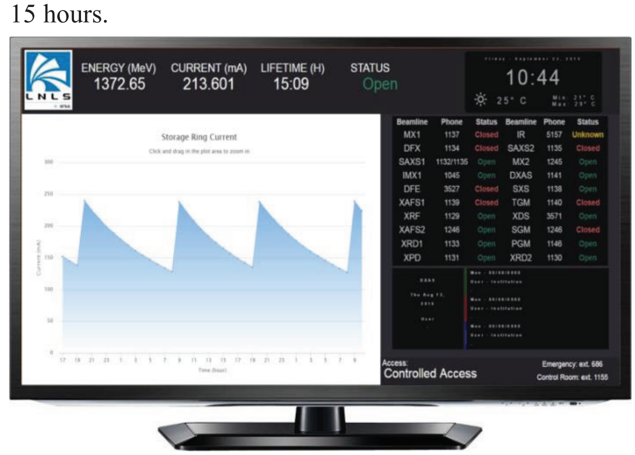

Figure 6: full frame display of Web-based storage ring status.

When the beamline status changes, the PPS’ PLC generates an interrupt signal to the Beaglebone board. A single Python script that is constantly running in each Beaglebone performs treatment of the signal.

The Python script uses the Adafruit GPIO library to read the interrupt signals and Pygame package libraries to

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search and load images in full-screen mode (see Figure 7). All this set of actions (digital signal variation + interrupt generation + search and loading of images) is performed in less than 150 ms. Pygame showed the fastest response to display images in comparison to other tested Python modules (OpenCV, Pillow, PyQT, etc.).

After extensive tests, Debian 7.5 (codename "Wheezy"), was found to be the most responsive operating system for the application.

Image Database

At Sirius, it estimated that tens of single board's computers, running this application, would be used. In this regard,3 maintainability must be optimized. All boards will share a common directory to access images. This will ensure that updates in the alert images database are common to all boards.

For this purpose, a Windows network point was created and mapped on all boards. Images were inserted into this network point and can be modified by any user with the appropriate permissions. Windows/Linux network mapping is done and managed using GNU/LINUX that supports Common Internet File System (CIFS) [4].

Automation Scripts

After the initial setup, the supervisory system operates autonomously (plug and play). Automation mechanisms were implemented using Shell scripts that run when Beaglebone boots up. These scripts have been implemented for two main purposes:

- Ensure standard Python script and web page, described above, are always running.
- Ensure Windows/Linux network mapping is achieved every time the board is restarted.

In order to perform a fast initial setup in a new Beaglebone board, another Shell script was developed. The script acquires and configures all modules used in the project. With this script, a new Beaglebone can be easily configured.

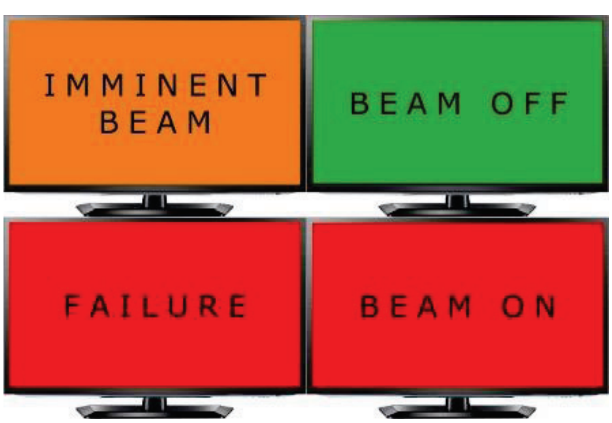

Figure 7: Examples of images showing Beamline Status on TV.

In order to perform a fast initial setup in a new Beaglebone board, another Shell script was developed. The script gets and configures all the modules used in the project. With this script, a new Beaglebone can be efficiently configured.

CURRENT STATUS

The system is under evaluation at the UVX machine. The Sirius' prototype hutch will receive the supervisory system and the PLC code must be developed to meet the logic required for full compatibility.

Moreover, an improved procedure for global edition (global upgrade) is also under development.

CONCLUSION

Based on the advance of the computer networks and low-cost, high resolution LED TV´s, web-based broadcasting supervisory system can provide concise and comprehensive information about the storage ring status.

Using low-cost single board computers, a new and modern supervisory system was successfully designed for Sirius' experimental stations. The proposed topology aims to provide readable warnings, useful information and customized sounds for the beamline users. People with Daltonism could now be warned about the beamline status.

During normal operation, the system provides machine status (storage ring parameters) using a web-based application. With respect to changes in the beamline mode of operation, interruption from PPS PLC's are treated by the system and relevant images (with priority) are shown on TV´s spread in the experimental station.

ACKNOWLEDGEMENT

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