# Beamline Supervisory System Using a Low-cost Single-board Computer

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## Abstract

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 Equipment Protection System (EPS) and Personnel Protection System (PPS). 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 for low cost, high flexibility, high expandability and an easy way to create fully customized warning messages for the users.

## 1. System Overview

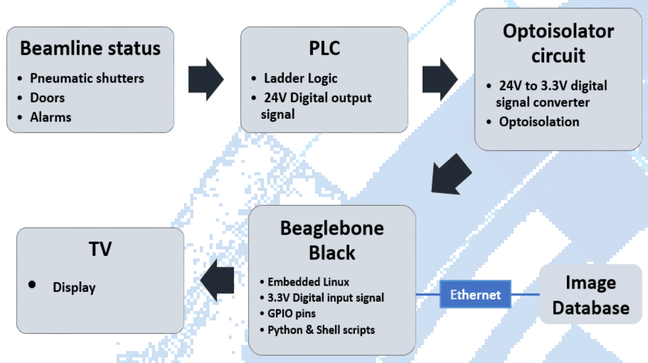


Figure 1: Supervisory system stages.

- Beaglebone Black 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, on-chip Ethernet, a USB host port and HDMI video interface.

## 2. Hardware Overview

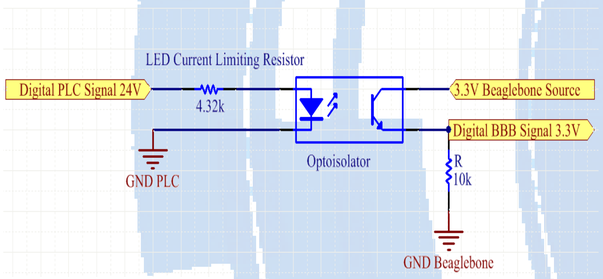


Figure 3: Opto-isolator circuit.

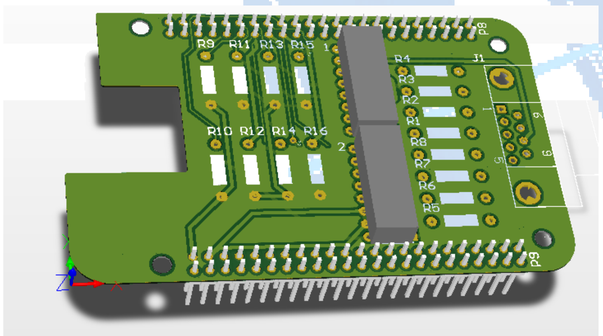

Figure 4: 3D view of the optocoupler circuit mezzanine board prototype.

- The PPS is an engineered interlock system that monitors the various devices installed in the beamline, for personnel safety and provide emergency beam shutdown
- **Beamline status** is determined by each PPS
- PLC sends beam line status to the signal conditioner mezzanine board (Figure 4)

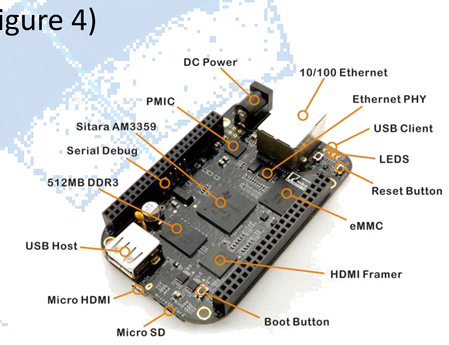


Figure 2: Beaglebone Black.

### The mezzanine board

- Once the beamlines mode is determined by PPS, the PLC send digital signals to the signal conditioner mezzanine board. **The mezzanine board translates the 24V logic level from PLC to 3.3V low voltage TTL used by the Beaglebone board** (see Figure 3 and 4).
- TTL signals are then sent directly to the GPIO pins.
- Board interprets the signals received and shows the proper image through HDMI video output.

## 3. Operation Example

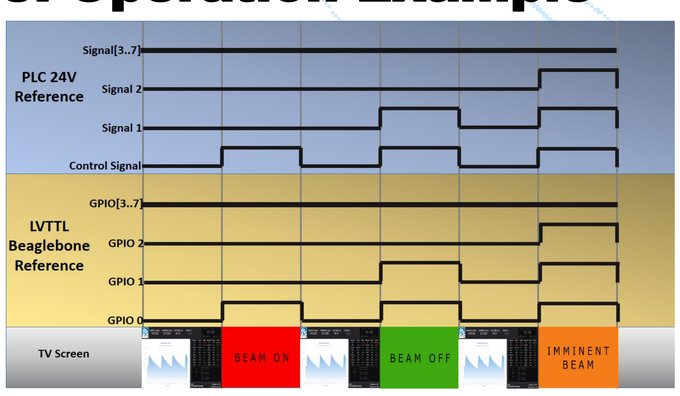


Figure 5: Example of timing diagram illustrating the TV screen from the digital signals at the input.

- This timing diagram illustrates how the software handles the signals received by the CLP disregarding possible propagation delays.
- 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).

## 4. Software Overview

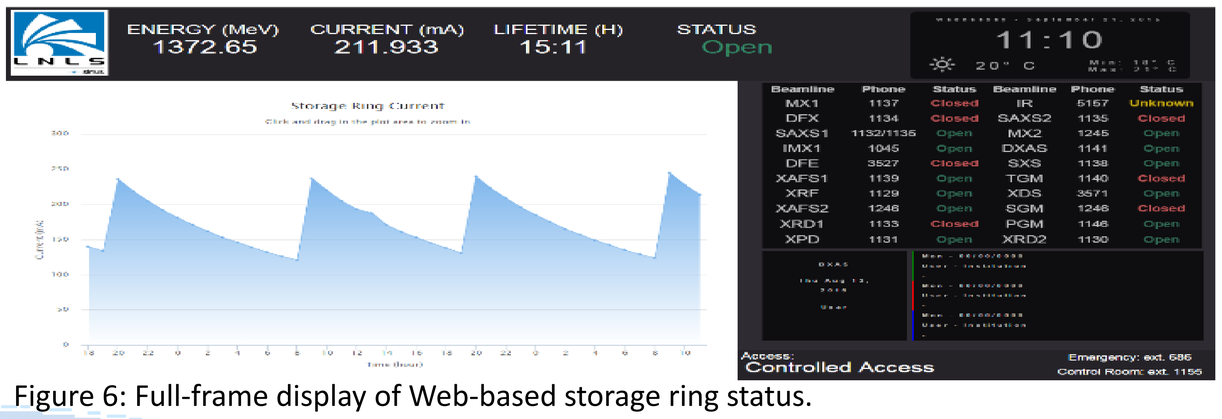


Figure 6: Full-frame display of Web-based storage ring status.

### Operating System

- **Debian 7.5 "Wheezy"** is **the most responsive operation** system for this application.

### Software

- 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
- Python script uses the **Adafruit GPIO library to read the interrupt signals** and **Pygame package libraries to search and load images in full-screen mode** (see Figure 7)
- Pygame showed the fastest response to display images in comparison to other tested Python modules (OpenCV, Pillow, PyQT, etc.)

### Image Database

- Tens of single board's computers, running this application, would be used simultaneously
- **All boards will share a common directory to access images.** The reason is **to ensure that updates in the alert images database are common to all boards.**
- 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)

### Automation Scripts

- After the initial setup, the **supervisory system operates autonomously** (plug and play)
- Shell scripts were implemented to ensure:
  - Python and standard web page described above are always running
  - Windows / Linux network mapping done every time the board is restarted
  - A new Beaglebone can be easily configured

## 5. Current status

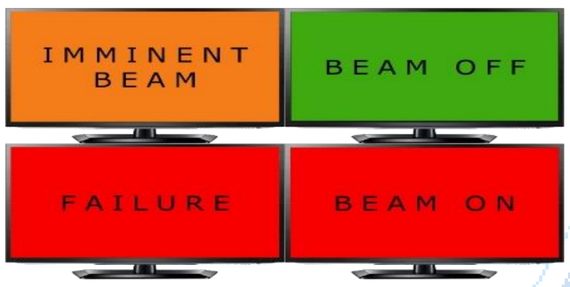


Figure 7: Examples of Photon Beam Status on TV.

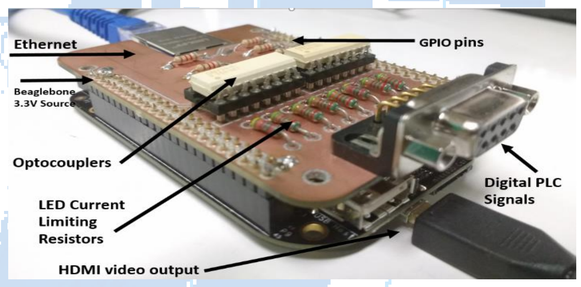


Figure 8: Prototype cape embedded in Beaglebone.

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.

## 7. 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.

## Acknowledgement

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