AN UPDATE ON CONSYS INCLUDING A NEW LABVIEW FPGA BASED LLRF SYSTEM

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Abstract

ConSys, the Windows based control system for ASTRID and ASTRID2, is now a mature system, having been in operation for more than 15 years. All the standard programs (Console, plots, data logging, control setting store/restore etc.) are fully general and are configured through a database or file. ConSys is a standard publisher/subscriber system, where all nodes can act both as client and server. One very strong feature is the easy ability to make virtual devices (devices which do not depend on hardware directly, but combine hardware parameters.)

For ASTRID2 a new LabVIEW based Low-Level RF system has been made. This system uses a National Instruments NI-PCIe 7852R DAQ card, which includes an on-board FPGA and is hosted in a standard PC. The fast (50 kHz) amplitude loop has been implemented on the FPGA, whereas the slower tuning and phase loops are implemented in the real-time system. An operator interface, including live plots from the regulation loops, are implemented in a host program on Windows. All three levels have been implemented with LabVIEW. The LLRF system is interfaced to ConSys through LabVIEW shared variables.

STATUS OF CONSYS

ConSys was originally made as a new control system for the storage ring ASTRID in 1998 [1-3]. It is now used at several machines at the University of Aarhus, which is including the new storage ring ASTRID2 [4] presently being commissioned. ConSys is also used at Stockholm University to control DESIREE and previously CRYRING as well.

The control system follows the standard model for a distributed control system using the publisher/subscriber method. It is running on Windows and written in Microsoft Visual C++ using MFC base classes. The design of the system is based on an object oriented programming strategy and the core system has been stable for many years. In ConSys the same core software is running on all computers - operator console PC's as well as frontend computers/device servers. Almost all configurable data are stored centrally in a SQL database: This includes all address information needed to locate devices and parameters, scaling data for conversion between binary and physical information, and display information used by a general purpose operator console application to generate operator pages for control and monitoring.

ConSys Devices

Data are collected and controlled on frontend computers through ConSys devices [1]. A large number of different hardware can be controlled and monitored by ConSys. Some hardware is controlled by dedicated devices where the device interfaces needed are coded directly into ConSys. Other equipment is controlled through analogue and digital I/O through general hardware. These kinds of hardware are serviced by standard ConSys devices where all configurable information is stored in the SQL database. At ASTRID we use home built equipment, as well as industrial systems. In the original control system all general control was done through home built so-called G64 systems – small CPU crates with general purpose analogue and digital control – including table based ramping of the machine. Most of these systems are still running today. Newer systems with need for general I/O are now based on Beckhoff PLC (Programmable Logical Controller) systems. PLC systems are relatively cheap, reliable and flexible systems for slow control and data acquisition. Simple automation codes are in some cases made directly in the PLC controller. Examples of programs implemented in PLC systems are: vacuum baking control, vacuum interlock/safety systems, personal safety system, undulator safety system and general averages of ADCs. All PLC systems are connected via Ethernet and serviced by a general ConSys PLC device for monitoring and control. As with our existing general devices all address and conversion information needed by ConSys to service the PLC's is stored in the central SQL database.

Another kind of general purpose I/O device is an interface device to LabVIEW shared/network variables. ConSys supports read and write of simple parameter types (Boolean, Word, Floating point) to shared variables. The shared variable names, location and data types are stored centrally in the SQL database. This device is used with NI CompactDAQ and CompactRIO systems as well as the LabVIEW based RF system presented later in this article.

A similar device is used to interface EPICS channels. The ConSys to EPICS channel interface is used for control and monitoring of the ASTRID2 beam position system, which is based on Libera Electron Beam Position Processors running an EPICS device.

Some hardware have embedded processors with control and monitoring through various interfaces. For this kind of hardware, specialized ConSys devices are implemented. The implementation is made so several instances of the same kind of hardware can be controlled by the same device code. This implies that all instance

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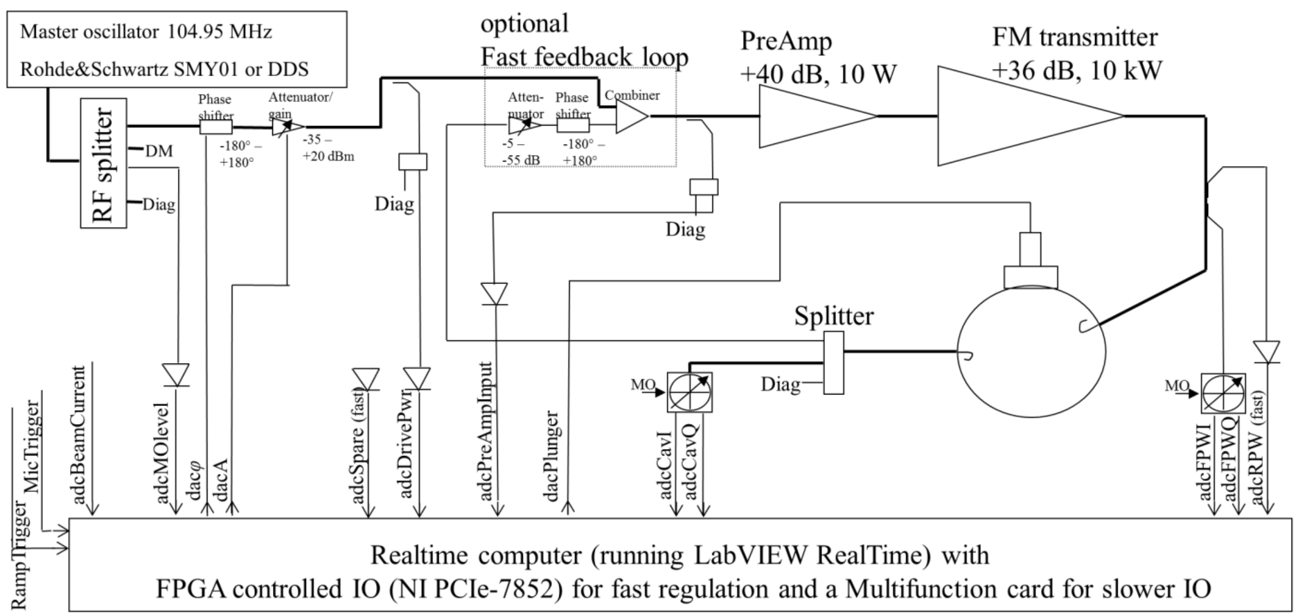

Figure 1: Overview of the ASTRID/ASTRID2 RF systems.

related information, like addressing, is stored in the SQL database. Examples of this kind of devices are power supplies, vacuum gauge controllers, pump controllers and motor controllers. Preferably all devices are connected directly to Ethernet. However, a lot of hardware only has serial port communication. To bring this kind of equipment to Ethernet, Moxa serial port TCP server boxes are used.

ConSys Parameters

In ConSys a parameter is defined as a single simple I/O point of a basic value type like a Boolean, a Word or a Floating point value. An I/O point can be a physical input or output from a piece of hardware or a virtual value stored in the memory of a ConSys device. Parameters are grouped into clusters with all parameters in a cluster having a common cluster name. Each parameter in the cluster has a specific name, in ConSys called a surname. The name of a parameter in ConSys is specified by <cluster name>.<sur name>, like 'BMH100IPSast2.Iw'. A cluster typically relates to a specific piece of hardware, like a power supply, and hence parameters in the cluster are all connected to the same ConSys device. There is, however, no binding on the source of parameters in a cluster. Parameters in a cluster can come from several different devices. This is useful in situations where calculated parameters from automation devices can be mixed with physical values from the device servicing the hardware. A simple example of this is a power supply for a magnet: physical values like current and voltage from a hardware device can be grouped in the same cluster as calculated values for power and magnet field from a calculation device.

Automations

Any ConSys parameter can be accessed from any machine - even other frontend computers. This feature is used in automation processes. ConSys strongly supports implementation of automations and many automatic reactions/functions/calculations are implemented at ISA. An example is synchrotron radiation operation: the steps involved in operation are heavily automated. This includes copying different settings for store and accumulation, automatic RF power control, etc.

ConSys Applications

ConSys has a set of generic applications for display, control and automation. The 'Console' program is the main program to display and adjust parameters. It is machine independent - all console pages are fully defined in the SQL database. A console page is built from a selection of clusters, or subset of clusters. Graphic pages based on any graphical background with overlaid parameters are also possible. An important feature of the console is the two control bars, where analogue parameters can be dragged to and controlled in several ways – of which the control through a small homebuilt panel with two digital potentiometers for an 'analogue feel' is the most convenient.

The 'Datalogger' program is used to log ConSys parameters to the SQL database. The parameters to be logged are collected into parameter groups. Each group is logged at fixed user defined intervals. Conditions for logging can be set based on ConSys parameters. z

'CSPlot' is the general purpose plot program for ConSys. CSPlot can plot any parameter, and have an unlimited number of graphs in each window. At start up, history buffers are obtained from ConSys devices. All ConSys devices store read and write histories for almost

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all parameters in memory. Typical history lengths are 2 weeks of data (with data being compressed/averaged into larger and larger bins the older they get). If a parameter is logged in the database by the datalogger, the history for that parameter can be extended by reading data back from the SQL database.

LOW-LEVEL RF SYSTEM

The storage rings in Aarhus, ASTRID and ASTRID2, are fitted with a 105 MHz RF system. A new RF system was needed for the new synchrotron light source ASTRID2. Since the low level RF (LLRF) system for ASTRID was quite old and difficult to maintain, it was decided to start by updating the ASTRID LLRF and make an almost identical system for ASTRID2. The systems use a digital control of baseband signals, with IQ demodulation for measurement, and direct amplitude and phase control for regulation. The control is done using a DAQ card which samples the baseband signals using ADCs and provides the control voltages using DACs. All software is programmed in National Instruments LabVIEW (version 2012).

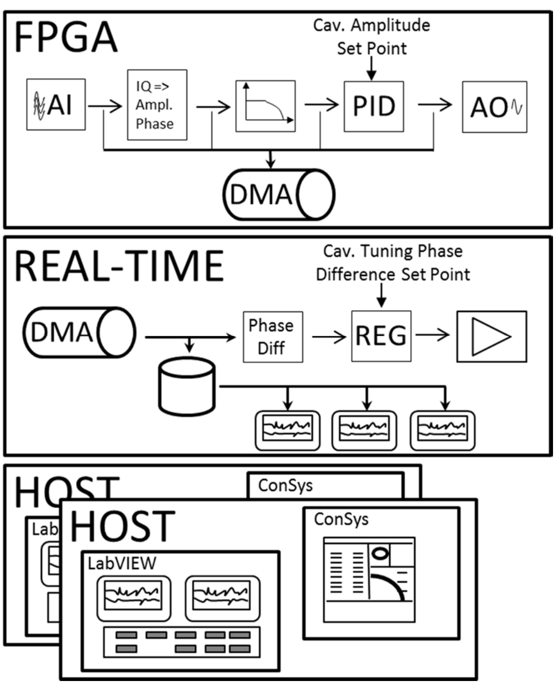

Figure 2: LLRF Software layers.

RF Hardware

Figure 1 shows an overview of the ASTRID/ASTRID2 RF systems. Input from a 105 MHz master oscillator is split into several lines. One part is sent through a voltage controlled phase-shifter, a voltage controlled attenuator and a low-power amplifier, before driving the high power amplifier. To be able to detect both amplitude and phase (full 360°) of the cavity pickup and forward power, IQ demodulators are used. The outputs of the IQ demodulators are at baseband (i.e. in principle DC signals). Amplitude detection of other relevant signals (reflected power, drive power, etc.) are done using simple power level detectors.

Tuning of the cavity on ASTRID is done with two plungers moved by DC motors. On ASTRID2 tuning is done by adjusting the cavity end plate using a stepper motor and appropriate mechanics.

Data Acquisition

The digital control is based on a standard industry PC with an Intel Core I7 processor. The system is equipped with a fast DAQ card - a National Instruments PCIe-7852R, with an onboard Virtex-5 LX50 FPGA, 8 AI, ±10V, 16 bit, 750 kS/s/ch; 8 AO, ±10V, 16 bit, 1 MS/s/ch. This fast card samples (500 kS/s) all fast varying signals (cavity pickup (IQ), forward power (IQ), and reflected power). In addition a slower multifunction card, a NI PCIe-6323, X series card with 16 AI, 250 kS/s, 16 bit; 4 DAC, 900 kS/s), 16 bit; 48 DIO, is used to detect other, slower varying signals, like master oscillator power.

Software Description

The RF software has three layers - FPGA, real-time and host program, see Figure 2. In the FPGA of the fast DAQ card amplitude and phase signals are calculated from the I and Q signals from the IQ demodulators. The cavity amplitude signal is, via a PID loop on the FPGA used to regulate the drive power through a voltage controlled attenuator. The bandwidth of this loop is ~50 kHz.

All signals (both I and Q and amplitude and phase) are via DMA sent to the real-time program. In the real-time program the phase difference of the cavity signal and the forward power signal is used to control the tuning of the cavity. The regulation here is a simple limit crossing algorithm. The advantage of a limit crossing algorithm is that the tuning motors are actuated less often, reducing wear.

The real-time program has all the controls and indicators, including plots, to operate the system. However since the system will be head-less (no screen) in normal operation, almost all control and indicators are also available through Shared Variables and data streams for fast plot data. A LabVIEW host program access these Shared Variables and data streams allowing full remote operation of the system including plots to monitor RF (baseband) and regulation signals. ConSys is also, through the general Shared Variable device, able to access all simple control and status.

REFERENCES

[1] K.T. Nielsen et.al: "ConSys - A CONTROL SYSTEM WITH A HIGH DEGREE OF ABSTRACTION", Proc. of PCaPAC'99, KEK, Tsukuba, Japan, poster P24.
[2] J.S.Nielsen, K.T.Nielsen and T.Worm: "ConSys – A new control system for ASTRID and ELISA", TUP46G, EPAC98.
[3] www.isa.au.dk/consys
[4] S.P. Møller, N. Hertel, J.S. Nielsen: "Status and very first commissioning of the ASTRID2 synchrotron light source", TUPPP003, IPAC2012.

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