MONITOR SYSTEM OF RF WAVEFORM STABILITY OF J-PARC LINAC

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Abstract

The RF power source of J-PARC LINAC is required to maintain a correct accelerating field within 1% for amplitude and 1º for phase. To monitor the RF waveform stability, a commercial oscilloscope is used for each RF module. An EPICS IOC is developed to control the oscilloscope, which is embedded inside the oscilloscope. This paper describes the detail realization and the current status of monitor system of RF waveform stability.

INTRODUCTION

The J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator, which consists of a 181-MeV LINAC, a 3-GeV RCS (Rapid Cycling Synchrotron) ring, and a 50-GeV MR (Main Ring) ring.

In the LINAC, there are 24 RF stations are used to provide a desired H^- beam. Those stations are powered by 20 3-MV klystrons and 4 solid-state-power amplifiers, and operated at a frequency of 324-MHz as Fig. 1 demonstrated.

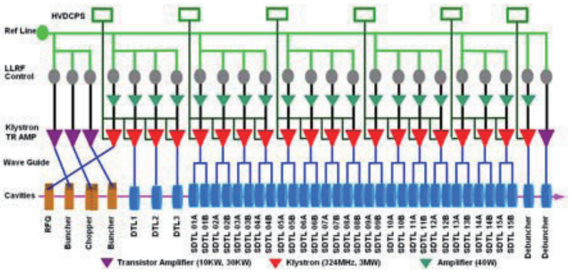

Figure 1: Layout of RF power source of LINAC.

The beam outputted from the ion source is accelerated to 3-MeV using a RFQ (Radio Frequency Quadrupole). A longitudinal matching is performed using 2 bunchers before injecting the beam to DTL (Drift Tube LINAC), which is installed in the MEBT1 (a beam transport line between RFQ the DTL) section. 2 choppers are installed in the MEBT1 to chop the beam. The beam is accelerated from 3-MeV to 50-MeV using 3 DTL cavities, and to 181-MeV using 15 SDTL (Separated-Type DTL) stations. Each SDTL station consists of 2 cavities and is driven by one klystron. 2 debuncher are installed at the end of LINAC to perform a longitudinal matching before injection the beam to the RCS ring.

The RF source is required to maintain a correct accelerating field within an amplitude error of ±1% and a phase error of ±1º. A DSO, the Infiniium 54832B oscilloscope from the Agilent Company, is used to monitor the RF waveform stability.

An EPICS (Experimental Physics and Industrial Control System) [1] IOC (Input Output Controller) [2, 3] is developed to control the oscilloscope remotely. It acquires the waveform data, analyses and fits the data using a Least-Square Method algorithm dynamically, and presents the result. The IOC is embedded inside the DSO to reduce the system cost since it uses the MS Windows XP as its underlying operating system.

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SYSTEM CONFIGURATION

A RF drive system distributes a 312-MHz master clock signal to a LLRF (Low Level Radio Frequency) station [4], which is synchronized with a 12-MHz timing master clock. The 312-MHz signal is down converted to 12-MHz clock. Then a 324-MHz clock is generated at the LLRF station, and distributed to a RF station such as RFQ, DTL and SDTL as Fig. 2 showed [4 ~ 6].

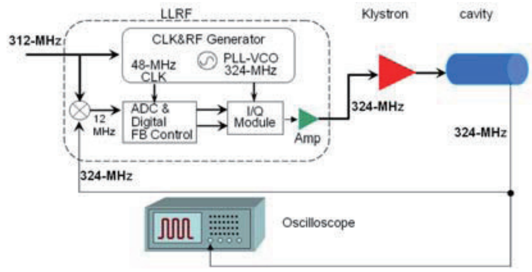

Figure 2: 324-MHz Clock Signal.

The DSO picks up 4 waveform signals: two from the pick-ups of one RF station, one from the front station, and the reference signal. The relationship between the DSO channel and pick-up is illustrated in Fig. 3.

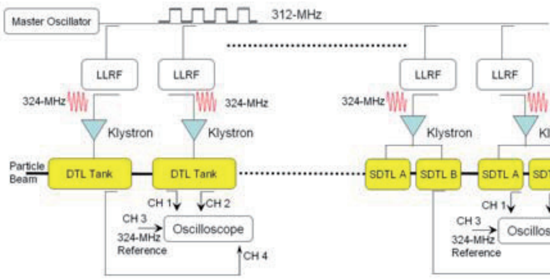

Figure 3: Relationship of Signal Pick-up DSO Channel.

The waveform signal is processed in the embedded EPICS IOC. All signals are processed to calculate the signal phase, the amplitude, the offset, and the phase difference with reference signal.

EPICS IOC

The EPICS, which is a software toolkit for control system development, is adopted as the framework by the J-PARC control system. The remote control for the DSO is developed under the EPICS framework.

EPICS Driver

An EPICS driver has been developed against the EPICS release 3.14.x under Linux operating system in J-PARC Control Group [7]. It supports various oscilloscopes including the Infiniium 54832B. The driver architecture is demonstrated as Fig. 4.

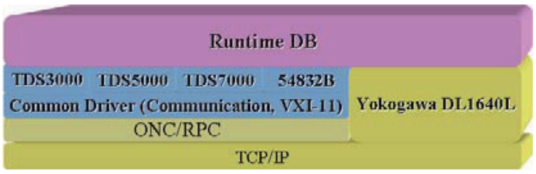

Figure 4: Schematic of EPICS Driver Architecture

The Infiniium 54832B DSO is controlled using GIPB (General Purpose Interface Bus) commands. The command and result are transmitted over Ethernet using the VXI-11 protocol, which is based on the RPC (Remote Procedure Call) protocol.

An example system is illustrated in Fig. 5 using the driver to control the DSO. The IOC runs on a standalone computer, which can be a vxWorks or a Linux station. The IOC is connected to the DSO and an OPI (Operator Interface) via Ethernet. IOC uses the VXI-11 protocol to communicate with the DSO, and uses an EPICS channel access protocol to communicate with the OPI.

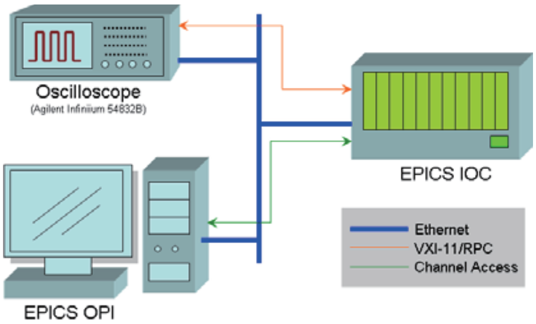

Figure 5: An Example using the Driver.

Driver Porting

The DSO used for the RF waveform stability monitor, adopts the Windows XP as its underlying operating system. To reduce the system cost, it is desirable to run the EPICS IOC inside the DSO as Fig. 6 illustrated.

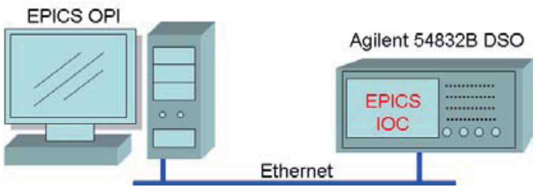

Figure 6: Embedded IOC inside DSO.

In principle, a driver based on the EPICS OSI (Operating System Independent) library can be used directly on various modern operating systems supported by the EPICS including the Windows XP. As Fig. 4 illustrated, this driver utilizes the VXI-11 library. The VXI-11 is based on the RPC protocol, uses the ONC (Open Network Computing) as a practical realization, which was proposed by the Sun Microsystems Inc.

The ONC/RPC is supported by many UNIX-like systems such as Linux, vxWorks, and so on. Unfortunately, the Windows XP uses a different RPC realization proposed by Digital Equipment Corporation, DEC/RPC (Distributed Computing Environment). The 2 realizations do not communicate seamlessly between each other as expected. The main problem is that these 2 RPCs present their data in different formats, and pass parameters in a differed way. Runtime routines and their corresponding stubs also lack interoperability between these 2 realizations.

It is necessary to port the driver to the Windows XP to embed the IOC into the DSO. A convenient solution is to port the ONC/RPC library because it is a conventional library and there are many existing porting available from the internet. An ONC/RPC package ported for Windows is adopted to run the driver on the Windows XP, which is hosted by the Chair of Process Control Engineering of Aachen University of Technology. It is available from reference [8], including source code and binary distribution.

Data Acquisition

To acquire a waveform data from the DSO, a readout request is sent by an IOC thread first. The driver processes the request using waveform readout function, and transmits it to the DSO communication task. The communication task sends a GPIB command to the DSO using the VXI-11 protocol. After processing the GPIB command, the waveform data is transmitted from the DSO to the communication task, and finally to the thread. The schematic of communication is illustrated in Fig. 7.

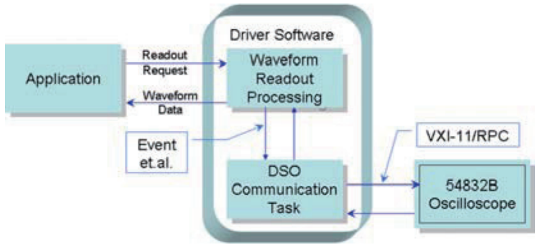

Figure 7: Schematic of Waveform Data Acquisition.

The waveform data acquired from the DSO is calculated inside the IOC. A data processing routine is developed to fit the waveform signal using a LSM (Least Square Method) algorithm is utilized. The result is saved in an EPICS record including the raw waveform, the signal amplitude, and the phase. The difference result with the reference channel is calculated also, ad saved in a EPICS record.

RESULT

The IOC software has been installed in the DSO to control the DSO remotely. The result is archived using an archiving server with 1-Hz frequency for offline analysis.

Because the reference signal has been measured within an accuracy of ±0.06º [4, 6], the long-time deviation is concerned here. The result by the DSO of SDTL01 is shown as Fig. 8 and Fig. 9. The signals are picked from the pick-up of SDTL TANK-A, SDTL TANK-B, and DTL3, and sampled by the DSO using CH1, CH2, and CH4 respectively as Fig. 3 showed. The reference signal is sampled by the CH3. An average within 1 minute is performed, and the result is plotted in Fig. 8 and Fig. 9. The pink line is a trending, which is fitted with a 6-order polynomial function.

Fig 8 shows the phase difference deviation with the RF reference during one day beam study (about 10 hours) in June 2007. The fluctuation error is less than 0.3º for all 3 channels.

Fig. 9 shows the amplitude fluctuation result during one day beam study (about 10 hours), which is same with Fig. 8. The fluctuation error is less than 0.13%, 0.12%, and 0.24% for CH1, CH2, and CH4 respectively.

SUMMARY

The stability of RF power source is monitored using the Infiniium 54832B oscilloscope. An EPICS IOC has been developed and installed inside each oscilloscope. All data have been archived using an archiving server for offline analysis. The purpose has been achieved to maintain the system stability within 1% for amplitude and 1º for phase.

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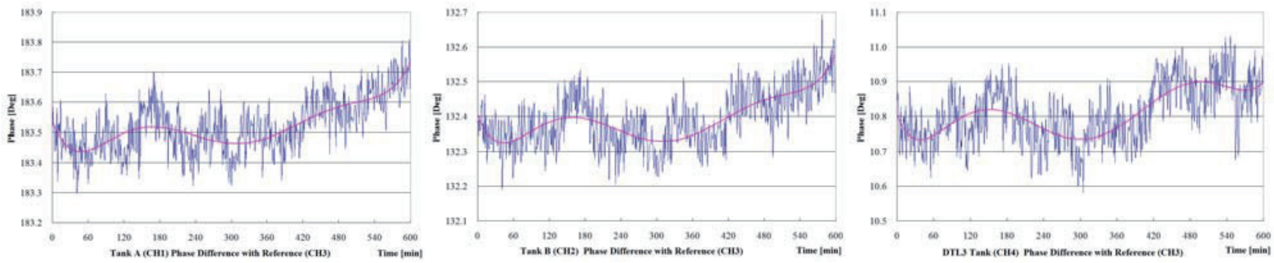

Figure 8: Fluctuation of Phase Difference with Reference from the Oscilloscope of SDTL01.

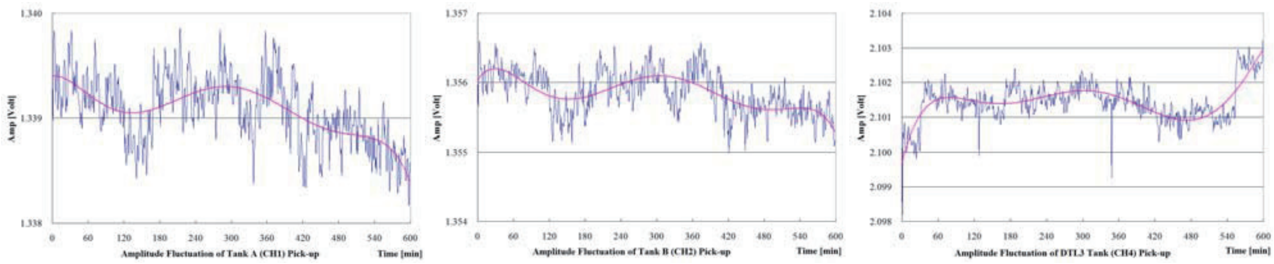

Figure 9: Amplitude Fluctuation from TANK Pick-up from the Oscilloscope of SDTL01.