NAPAC2016

An Updated LLRF Control System for the TLS LINAC

C. Y. Wu#, Y. S. Cheng, C. Y. Liao, Demi Lee, K. H. Hu, K. T. Hsu

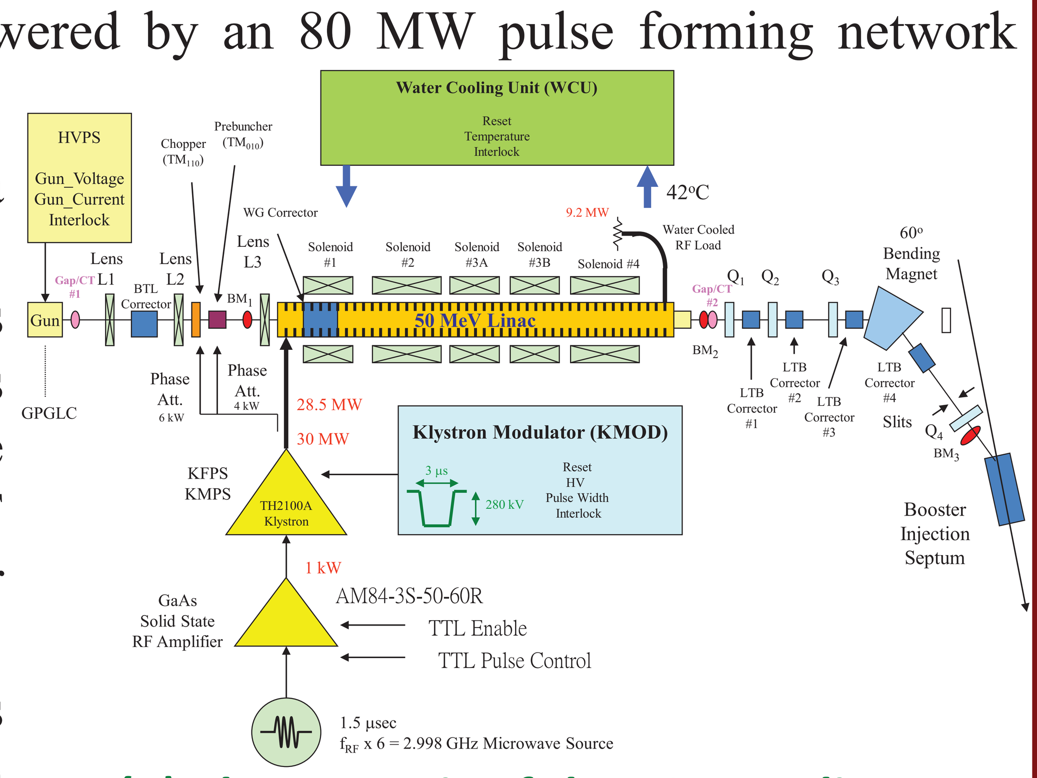
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

Abstract

The amplitude and phase of the RF field at the linear accelerator (LINAC) decides the beam quality. To study and to improve the performance of the LINAC system for Taiwan Light Source (TLS), a new design of a low-level radio-frequency (LLRF) control system was developed and set up for the TLS LINAC. The main components of the LLRF control system are an I/Q modulator, an Ethernet-based arbitrary waveform generator, a digital oscilloscope and an I/Q demodulator; these are essential parts of the LLRF feed-forward control. This paper presents the efforts to improve the LLRF control system. The feasibility of the RF feed-forward control will be studied at the linear accelerator of TLS.

LINAC System

- The pre-injector of the TLS consists of a 140 kV thermionic gun and a 50 MeV travelling wave type linear accelerator system. The synoptic view of the pre-injector is shown in Fig. (a).
- The microwave system was composed of a multiplier that derivate 2998 MHz from 499.654 MHz, a 1 kW GaAs solid state RF amplifier, and a high power klystron amplifier.
- The high power klystron is powered by an 80 MW pulse forming network (PFN) based modulator.
- The PFN is charged by a switching power supply.
- An analogue I/Q modulator is placed in front of the GaAs amplifier to control the amplitude and phase of the RF field fed into the linear accelerator.
- An analogue I/Q demodulator is used to detect the RF signal from outlet of the linear accelerator



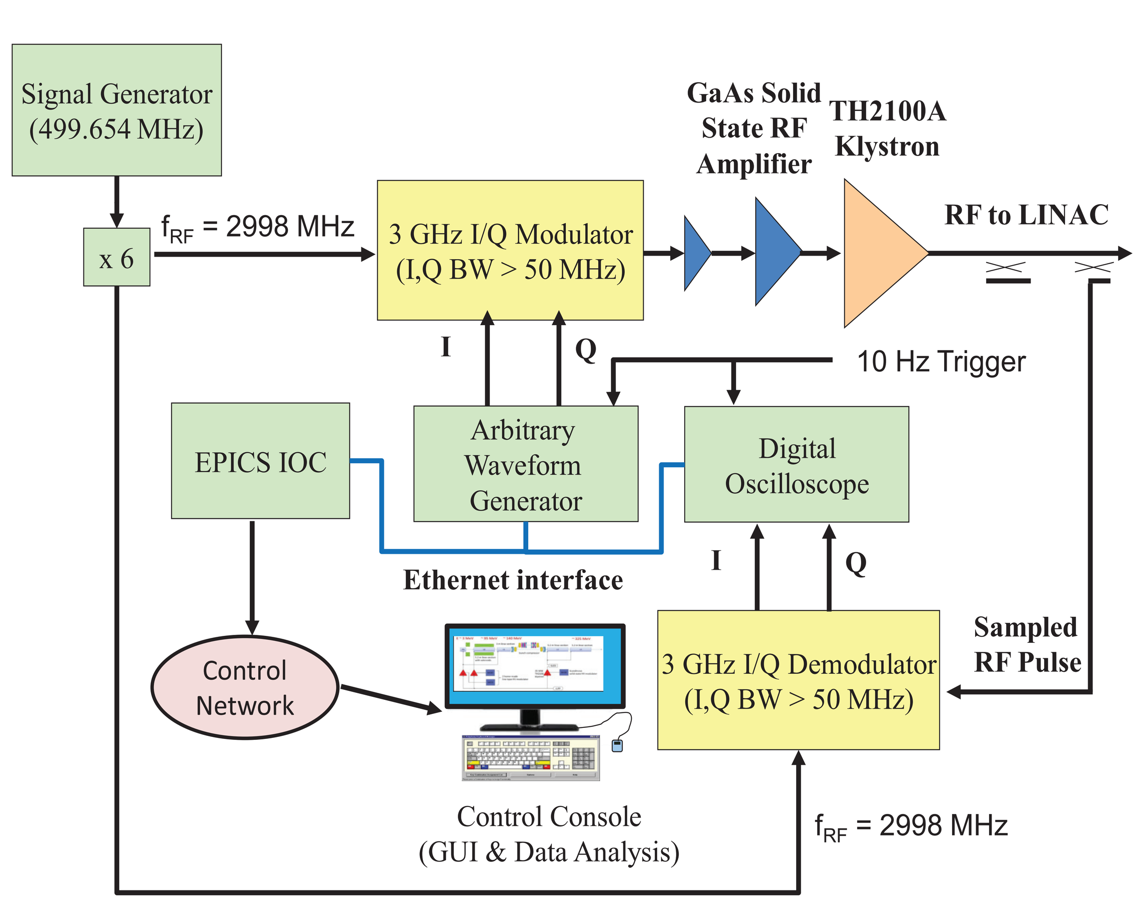
(a) The synoptic of the 50 MeV linear accelerator system of the TLS

LLRF System Description

- The system consists of a clock generator, an arbitrary waveform generator (AWG), an analogue type I/Q modulator, an GaAs solid state RF amplifier, a high power klystron and a klystron modulator, an analogue type I/Q demodulator, and a digital oscilloscope is shown in Fig. (b).
- The arbitrary waveform generator is used to generate in-phase (I) and quadrature-phase (Q) control waveform as an input of the I/Q modulator.
- One 250 MHz programmable AWG (33522A) are used for controlling I and Q signal, and the generator has a resolution of 16 bits in LLRF system.
- A digital oscilloscope (DSO9024H) are used for reading I and Q signal, and there has a resolution of 12 bits.
- The AWG and the oscilloscope are connected to the EPICS IOC via private Ethernet.
- Access of the AWG and the oscilloscope can be done in the EPICS environment.
- The pickup RF signal at LINAC output is detected by the I/Q demodulator to obtain in-phase and quadrature-phase (I and Q) components of the RF field.
- The amplitude A(t) and phase θ(t) of the RF signal can be reconstructed by the following equations:

$$A(t) = \sqrt{I^2(t) + Q^2(t)}$$

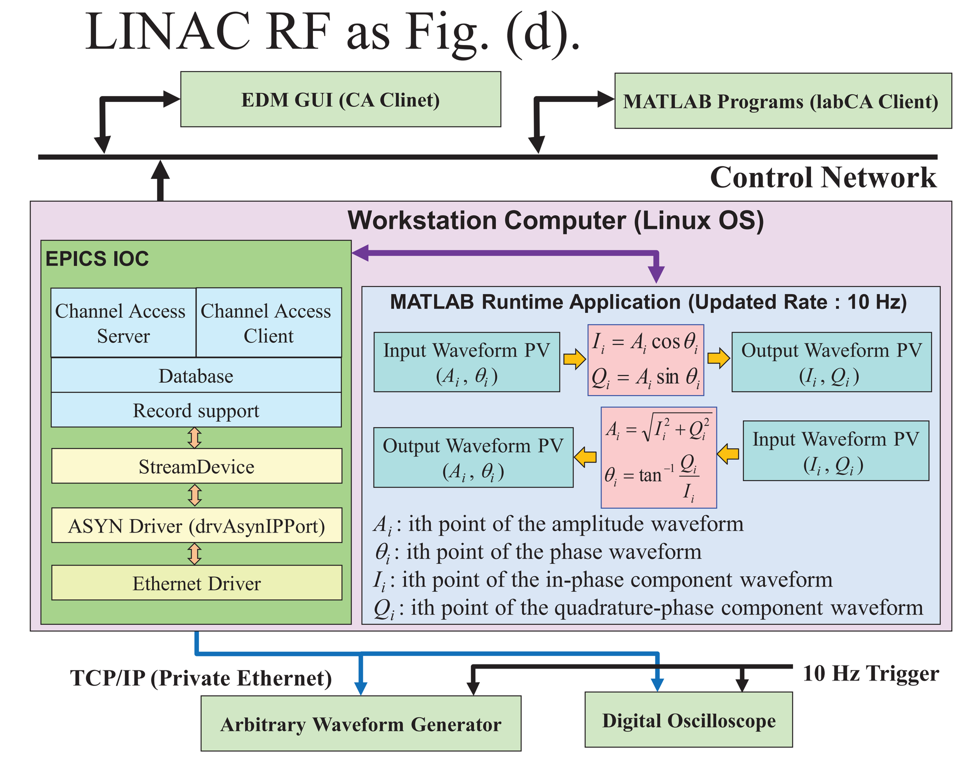
$$\theta(t) = \arctan(Q/I)$$



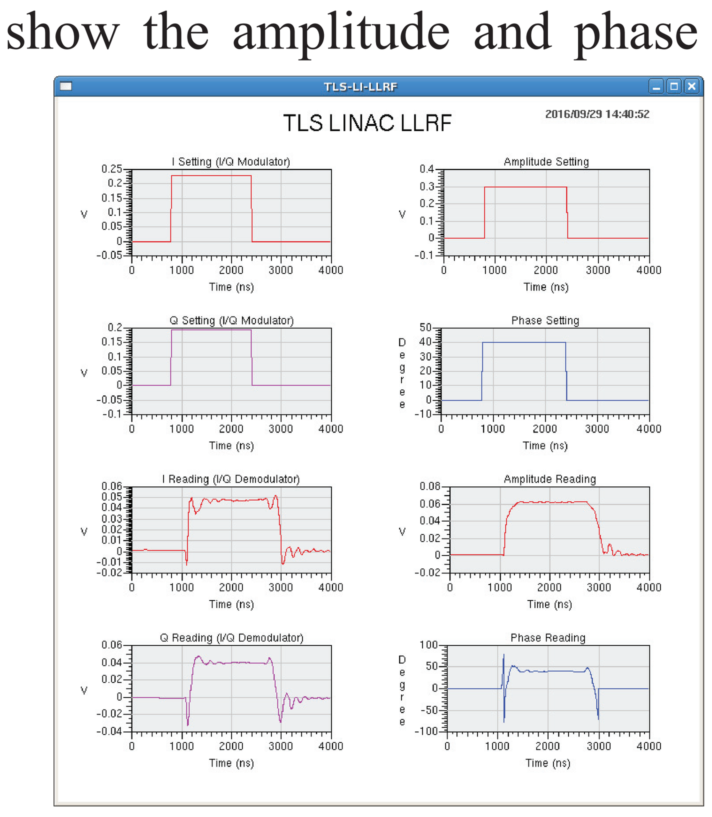
(b) Functional block diagram of the updated low level RF system for the 50 MeV linear accelerator

EPICS Waveform Support for LLRF System

- One dedicated EPICS IOC was set up to implement for EPICS support and communicates with the oscilloscope and arbitrary waveform generator via Ethernet interface.
- The StreamDevice and ASYN driver are needed, and employed to communicate with oscilloscope and arbitrary waveform generator.
- The related records of EPICS database have been created with link of the StreamDevice.
- One workstation computer is setup related EPICS environment as the EPICS IOC.
- The CA (channel access) client with OPI applications or labCA client with a MATLAB program can be used to access PVs from CA server.
- The amplitude and phase of LINAC RF setting/reading PV are derived from the MATLAB application in every 100 msec.
- The specific EDM page are created to show the amplitude and phase of LINAC RF as Fig. (d).



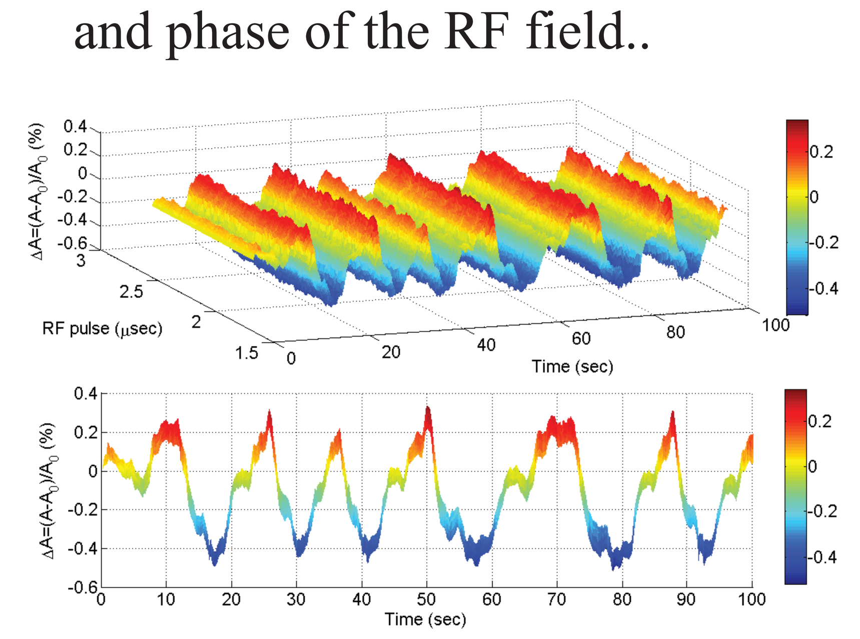
(c) Software block diagram of building EPICS support of arbitrary waveform generator and digital oscilloscope for LLRF control.



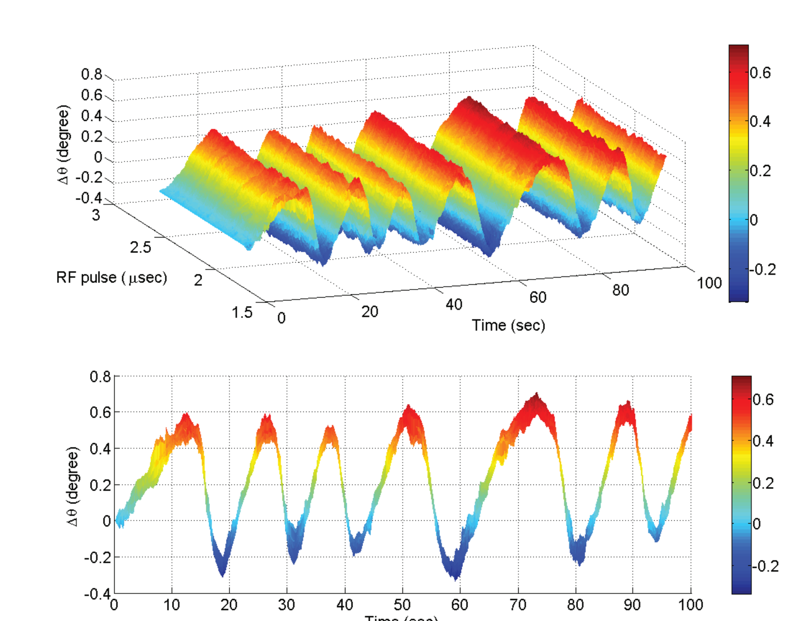
(d) GUI pages for observation the amplitude and phase waveform of LINAC RF field.

Performance of The LINAC RF Field

- The amplitude and phase of the LINAC RF field are recorded to observe the stability of the LINAC RF
- Fig. (e) shows that the variational amplitude of the LINAC RF field is about ± 0.3 % during 100 s .
- The phase drift of LINAC RF field is about ± 0.4 degree during 100 s without any correction is shown in Fig. (f).
- To cure amplitude and phase drifts of LINAC RF output, RF feed-forward control might be a solution to achieve improved performance.
- Apply RF feed-forward control can improve the flatness of the amplitude and phase of the RF field..



(e) Variational amplitude of the LINAC RF field. A denotes amplitude; $\Delta A=(A-A_0)/A_0$ is the amplitude drift.



(f) RF phase drift of LINAC output without correction. θ is the phase; $\Delta\theta = \theta - \theta_0$ is the phase drift.

Summary

- A preliminary test run of the updated LLRF control system has been performed at the 50-MeV linear accelerator of TLS.
- Various EDM pages for varied purposes were created for the operation of the LINAC LLRF system.
- The drift and flatness of the amplitude and phase of the linear accelerator RF pulse will be improved after correction.
- Several correction algorithms of the RF feed-forward control will be studied. Apply RF feed-forward correction is in plan.
- Efforts to improve the feed-forward control algorithm, RF electronics and data acquisition are continuing.
- The beam quality of the LINAC, in terms of its energy spectrum, is also continuing to be improved.

#E-mail: chunyiwu@nsrrc.org.tw

The American Particle Accelerator Conference (NAPAC) , TUPOA12, October 9 - 14, 2016