Generation of multiple analog pulses with different duty cycles within VME control system for ICRH Aditya system

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Abstract. Ion Cyclotron Resonance Heating (ICRH) is a promising heating method for a fusion device due to its localized power deposition profile, a direct ion heating at high density, and established technology for high RF power generation and transmission at low cost. Multiple analog pulse with different duty cycle in master of digital pulse for Data acquisition and Control system for steady state RF ICRH System(RF ICRH DAC) to be used for operating of RF Generator in Aditya to produce pre ionization and second analog pulse will produce heating.

The control system software is based upon single digital pulse operation for RF source. It is planned to integrate multiple analog pulses with different duty cycle in master of digital pulse for Data acquisition and Control system for RF ICRH System(RF ICRH DAC) to be used for operating of RF Generator in Aditya tokamak. The task of RF ICRH DAC is to control and acquisition of all ICRH system operation with all control loop and acquisition for post analysis of data with java based tool. For pre ionization startup as well as heating experiments using multiple RF Power of different powers and duration. The experiment based upon the idea of using single RF generator to energize antenna inside the tokamak to radiate power twice, out of which first analog pulse will produce pre ionization and second analog pulse will produce heating.

The whole system is based on standard client server technology using tcp/ip protocol. DAC Software is based on linux operating system for highly reliable, secure and stable system operation in failsafe manner. Client system is based on tcl/tk like toolkit for user interface with c/c++ like environment which is reliable programming languages widely used on stand alone system operation with server as vxWorks real time operating system like environment. The paper is focused on the Data acquisition and monitoring system software on Aditya RF ICRH System with analog pulses in slave mode with digital pulse in master mode for control acquisition and monitoring and interlocking.
1. Introduction

The control system software is based on pulse operation of RF source which is using digital pulse, now will also integrated with multiple analog pulse with different duty cycle in master of digital pulse for Data acquisition and Control system for steady state RF ICRH System (RF ICRH DAC) to be used for operating of RF Generator in Aditya.

2. Block diagram

As shown in figure 1 the mechanism is to make analog pulses will be generated with using voltage variable attenuator in path of VME subsystem. VME hardware cards like ip220, vmivme2528 and ip480 is required to generate pulses in synchronous manner. System will generate analog pulse in slave with master digital pulse generated using VME hardware.

Before amplifying signal at the first stage, standard source of signal is required of fixed frequency in mhz range with variable low power. This function provided by signal generator (function generator). Once signal generator is set at higher power level (dbm) and output of last stage power control by RF voltage variable attenuator using variable analog control pulse.

Isolation and gain is provided by card contain into signal conditioning rack for generated Analog and digital pulses.

Hardware requirement

Since Data acquisition and control for ICRH system is based on VME bus system, so to generate this type of pulse VME compatible Analog output card IP-220 is used. From this card upto 10V can be obtained by software programming driver & integrating with VME system.

Timer Card: ICRH system requirement for safe operation is such that it needed External Digital output signal to trigger the RF signal generator from the DAC & as long as this digital pulse remains high, signal
generator keep providing RF signal of set operating frequency & amplitude to Low power amplifier (LPA) stage. For this VMIC-2528 card is programmed.

In case of any fault inside the RF tube or in HV power supply this DO trigger pulse from VME have to stop within micro-second to prevent the tube for permanent damages. For that this pulse is interlocked with all critical HV and auxiliary power supplies control signals, e.g. over-voltage, over-current, filament –off, cooling off, HV trip etc.

RF-Voltage attenuator: The function of RF voltage attenuator is to pass the RF signal present at its input section to output section as a function of control voltages present at its control pin.

3. **Software functionality & complexity**

Software uses the basic architecture of VME based software. The driver program will contains basic functionality as follows.

- avme9660 carrier board
- ip480 timer card
- ip220 analog output card
- vmi vme2528 digital i/o card
- avme9325 analog input card 2nos.

The basic functionality driver is provided which has class name bsp (board support package) which is required to communicate with VME processor as master and cards as slave mode. The bsp class is basic class, which inherits as avme9660 carrier board has non-intelligent board. On this board there is facility to mount 4 ip modules. We have mounted on ip220 and ip480 card on board. There is modular programming technique has been used which uses inherited classes named ip220 and ip480.

Vender provides IP480 timer card basic programming driver which has inherited by 9660 class which gives base address corresponding to user memory defined by architecture provided by processor board support package. Same as ip220 class provides analog output functionality, which is configured for 0 to 10V level.

There is a dynamic range defined into 0 to 10 voltage level. Analog pulse duration is defined as first delay-time, on-time1, off-time1, on-time2, off-time2. In these parameter delay-time is defined with delay time of Master Digital RF Pulse. The parameter of on-time1, off-time1, on-time2 will contain into digital on-time of pulse duration. on-time1 is defined with on-time of digital pulse which will on-time with some desired level of analog voltage defined by user into range of 0 to 10V. Also off-time1 is given within digital pulse. After that on-time2 is defined with desired voltage level defined by user, off-time2 will end the Analog pulse with digital pulse duration. The multiple pulse of Analog will generate with digital pulse given by user as number of pulse.

4. **Application program user interface**

Application program for client is working in synchronized with vme based driver program written in c/c++. There is little modification with client gui and make window provision for generating analog pulse in synchronize with digital pulse.
5. Complexity & its troubleshooting

While generating analog pulse in master of digital pulse there is some difficulties faced like this: The Analog voltage level may be floating value but in isr (interrupt service routine) that is routine which can be run while software or hardware trigger occurred with timer card (ip480) at most speed of 8Mhz. But there is some complexity for using floating point operation with isr so the value is taken as integer and work with customizing routine given with driver provided by ip module vender.

There is confliction on bsp class driver address and with corresponding with ip220 driver base address so processor is restarted with accessing ip220 board base address. Newer customized driver class is generated and that is synchronized with available base address of bsp means this class is inherited from bsp class and using word routine for 4 byte values provided by user.

There is one 1ms delay is introduced due to wrong calling of function for generation of digital pulse that has removed and make it cure by calling proper sequence of functions.

6. Testing Procedure

The pulse generation from different analog output and digital output channel is seen onto CRO after clicking onto dummy pulse shot. The duration for different above mentioned parameter is verified with given values onto CRO screen.

7. Protection

Generator gets triggered only when RF-Pulse applied from the VME as per experiment as requirement. Control voltage for the RF-Attenuator is synchronous with RF-shot pulse i.e. control voltage will generate only when RF-Shot signal is active. (it is software interlocked with rf-pulse)

If some fault occurs in the rf-tube or in the power supply within the given RF-shot duration, hardware interlock will sense the fault and terminate the RF-shot pulse to function generator.

Fig-3 is shows test setup of voltage variable attenuator with software screen(3C) for parameter setting to generate variable amplitude and variable duty cycle pulse. Fig-4 A is showing test result of setting for i/p 800w(-2.5dbm) & attenuator output of 165w. Same as 4B and 4C is using 500 and 100 watt setting results.
8. Test-setup

Fig -3(A,B,C) Test-setup of attenuator and LPA, biased PS & atten. & software screen

9. Test-results

Fig-4(A,B,C) Test-results of setting for i/p 800w(-2.5dbm) & attenuator output of 165w

Conclusion

The requirement of Aditya RF system is to deliver different output powers in different duty cycles within single digital pulse with use of multiple analog pulses of variable amplitudes. This requirement has fulfilled with use of software program and voltage variable attenuator as hardware device used with VME. This system is tested with dummy load up to 800 watts and is ready for the pre ionization & heating experiment on tokamak aditya. This system is also utilized for long pulse operation with steady state super conducting tokamak for 1000s operation.