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Programmable Pulse Generator for Aditya Gas Puffing System

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Abstract. In the Aditya Tokamak, one of primary requirement for plasma generation is to feed the required quantity of the fuel gas prior to plasma shot. Gas feed system mainly consists of piezoelectric gas leak valve and gas reservoir. The Hydrogen gas is prior to 300ms loop voltage for the duration of 4 msec to 7 msec. Gas is puffed during the shot for required plasma parameters and to increase plasma density using the same system. The valve is controlled by either continuous voltage or pulses of different width, amplitude and delay with respect to loop voltage. These voltage pulses are normally applied through standard pulse generator. The standard pulse generator is replaced by micro controller based in housed developed programmable pulse generator system consists of in built power supply, BNC input for external trigger, BNC output and serial interface. This programmable pulse generator is successfully tested and is in operation for gas puffing during ADITYA Tokamak experiments. The paper discusses the design and development aspect of the system.

1. Introduction

Hydrogen gas is fed to vacuum vessel for generation of plasma. It is also puffed during the plasma discharge to reduce impurities hard X-ray etc. and to maintain the density. The gas feeding system consists of piezoelectric gas leak valve and gas reservoir. Gas is puffed during plasma shot using same gas feeding system to reduce hard X-ray and increase plasma density. Additional Gas puffing helps in sustaining the plasma.

For puffing gas at various instances during plasma discharge, either continuous voltage or voltage pulses of different amplitude and widths are applied to piezoelectric valve (model MV112) to get desired Plasma parameter. A piezoelectric gas feed valve is routinely used for feeding the fuel gas in Tokamak. The valve is operated linearly with applied voltage. The duration and the amplitude of applied pulse decide the opening of the valve i.e. valve will open more if the amplitude is more and will remain open for longer time for longer pulse width. Opening is varying depending upon voltage and the pulse width of the applied pulse. The valve opened fully in 2 msec.

The piezoelectric valve is controlled by the controls available either from CAMAC pulse generator or from standard function generator. An in-housed microcontroller based programmable pulse generator (PPG) is designed and developed to generate these pulses to control the valve. The output of the programmable pulse generator is amplified with the gain of 20 and applied to the piezoelectric valve to match the required potential to operate the valve.

Basic idea for the in-housed development is to make the control operation independent of the data acquisition and control system and work as stand-alone user-friendly system. User can set the parameters like number of pulses, amplitude, width and delay using PC serial interface.

2. Theoretical Basis

Microcontroller has two timer registers. One of the timers is used to generate pulse of fixed pulse width for “fixed pulse width (100 μ sec) High level, TH loop” while second timer is used to generate pulse of fixed pulse width for “fixed pulse width (1msec) Low level, TL loop”.

TH = Number x TH loop

TL = Number x TL loop, Number is 8bit data fed by user.

On receiving the external trigger pulse, the program generates the desired delayed pulse. Data for pulse width, delay and Amplitude can be loaded using serial connectivity.

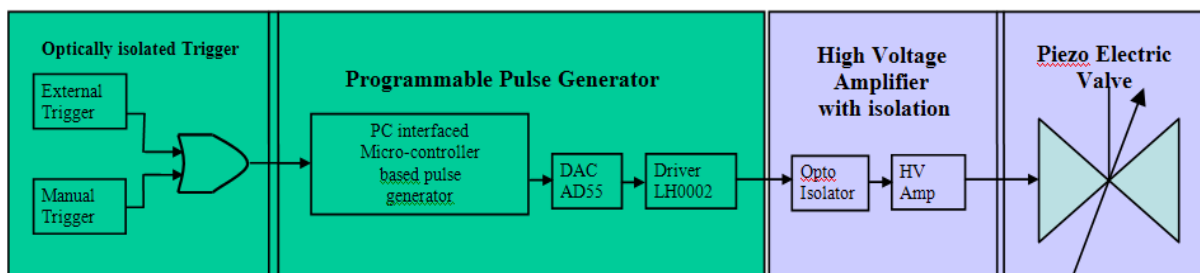


Fig. 1. Functional Block Diagram of PPG

As shown in the figure1 the system is developed in two halves. “Optically isolated external trigger and Programmable Pulse Generator” is one part which is installed in the Control room while second part “High Voltage Amplifier with isolation” is installed near piezoelectric Valve with Vacuum Control system.

Parameters are loaded to controller memory using serial text file transmitted using LabVIEW.

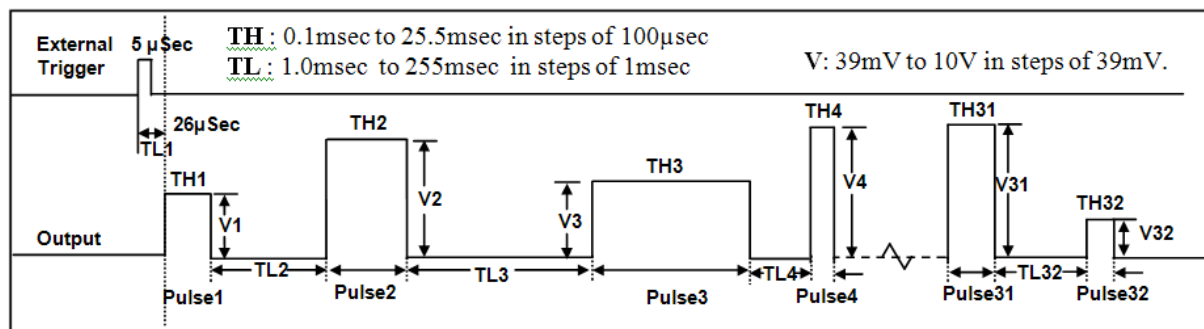


Fig. 2. Operational timing diagram of the system

To generate desired pulse following four main parameters are to be set: Total number of pulses (N), High time (TH) and Low time (TL) of each pulse and Amplitude (V) of each pulse.

As shown in the figure 2, the valve will be open for TH time and will close for TL time. Amplitude V will define opening or how much it will open and N will define for how many times the valve will be opened (gas will be puffed), Delay (TL1) will decide delay between Trigger and opening of Gate Valve.

3. Experimental set-up

In House developed programmable pulse generator is triggered by optically isolated signal conditioned loop voltage pulse. It generates pulses of different width (100 μ s to 25.5 ms in steps of 100 μ s), amplitude (0-10V in steps of 39 mV) and delay (between external trigger to first output and between different output from 26 μ sec to 255 ms in steps of 1 ms) using Digital to Analog converter. The pulse then applied to a high voltage amplifier with a gain of 20 to generate required potential to operate the valve. The amplified output is applied to the piezoelectric leak valve, to control the opening of the valve. Minimum delay from the external trigger pulse to the output is 26 μ sec.

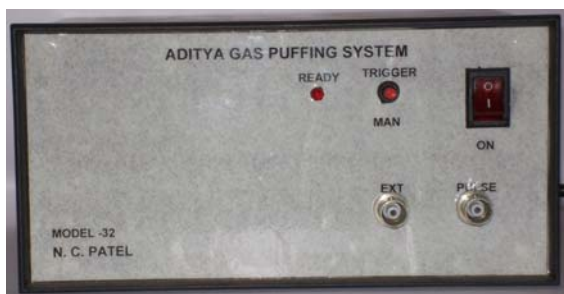


Fig. 3. Front Panel

As shown in the figure 3, the front panel has ‘Ready’ LED for indication of readiness of the system for data transmission or waiting for external trigger and a push button for Manual trigger. It has one SPST key for switching On/Off power supply. Programmable Pulse Generator output and optically isolated external trigger input are available on BNC connector while manual trigger is given by push button switch.

It has in-built regulated D C power supply which can be controlled by power ON switch on front panel-(figure 4). Programmable Pulse Generator is designed using AT89C52 micro controller, AD558 digital to analog converter, LH0002H output driver, IC 4N35 opto-coupler and MAX 232 serial converter. The parameter data text file is loaded to the controller memory through 9 pin D type serial connector and PC.



Fig. 4. System Circuit Assembly

4. Experimental results and Discussions

The experiment needs two stages

- 1) Sequence for setting parameters and
- 2) Receiving External trigger

4.1 Sequence for setting parameters

Generate an Excel file as shown in figure5. Column A (Type of parameter) describes name of parameter. Column B (Input data) is desired parameter. Column C is Converted data which will go to microcontroller memory.

For Offtime (TL), conversion is (data x 1).

For Ontime (TH), conversion is (data x 10).

For Amplitude (V), conversion is ((data x 1000) / 39) considering the DAC 558 parameter.

A	B	C	A	B	C	A	B	C
1 DATA ID	#	#	35 TH - 1 ms	0.1	1	67 Volt Pulse - 1	5	128
2 Pulse no.	32	32	36 TH - 2 ms	0.1	1	68 Volt Pulse - 2	3	77
3 TL - 1 ms	1	1	37 TH - 3 ms	0.1	1	69 Volt Pulse - 3	8	205
4 TL - 2 ms	1	1	38 TH - 4 ms	0.1	1	70 Volt Pulse - 4	4	103
5 TL - 3 ms	1	1	39 TH - 5 ms	0.1	1	71 Volt Pulse - 5	2	51
6 TL - 4 ms	1	1	40 TH - 6 ms	0.1	1	72 Volt Pulse - 6	9	231
7 TL - 5 ms	1	1	41 TH - 7 ms	0.1	1	73 Volt Pulse - 7	4.5	115
8 TL - 6 ms	1	1	42 TH - 8 ms	0.1	1	74 Volt Pulse - 8	3.5	90
9 TL - 7 ms	1	1	43 TH - 9 ms	0.1	1	75 Volt Pulse - 9	1.5	38
10 TL - 8 ms	1	1	44 TH - 10 ms	0.1	1	76 Volt Pulse - 10	1	26
11 TL - 9 ms	1	1	45 TH - 11 ms	0.1	1	77 Volt Pulse - 11	9.5	244
12 TL - 10 ms	1	1	46 TH - 12 ms	0.1	1	78 Volt Pulse - 12	1	26
13 TL - 11 ms	1	1	47 TH - 13 ms	0.1	1	79 Volt Pulse - 13	2	51
14 TL - 12 ms	1	1	48 TH - 14 ms	0.1	1	80 Volt Pulse - 14	3	77
15 TL - 13 ms	1	1	49 TH - 15 ms	0.1	1	81 Volt Pulse - 15	4	103
16 TL - 14 ms	1	1	50 TH - 16 ms	0.1	1	82 Volt Pulse - 16	5	128
17 TL - 15 ms	1	1	51 TH - 17 ms	0.1	1	83 Volt Pulse - 17	6	154
18 TL - 16 ms	1	1	52 TH - 18 ms	0.1	1	84 Volt Pulse - 18	7	179
19 TL - 17 ms	1	1	53 TH - 19 ms	0.1	1	85 Volt Pulse - 19	8	205
20 TL - 18 ms	1	1	54 TH - 20 ms	0.1	1	86 Volt Pulse - 20	9	231
21 TL - 19 ms	1	1	55 TH - 21 ms	0.1	1	87 Volt Pulse - 21	9.5	244
22 TL - 20 ms	1	1	56 TH - 22 ms	0.1	1	88 Volt Pulse - 22	9	231
23 TL - 21 ms	1	1	57 TH - 23 ms	0.1	1	89 Volt Pulse - 23	8	205
24 TL - 22 ms	1	1	58 TH - 24 ms	0.1	1	90 Volt Pulse - 24	7	179
25 TL - 23 ms	1	1	59 TH - 25 ms	0.1	1	91 Volt Pulse - 25	6	154
26 TL - 24 ms	1	1	60 TH - 26 ms	0.1	1	92 Volt Pulse - 26	5	128
27 TL - 25 ms	1	1	61 TH - 27 ms	0.1	1	93 Volt Pulse - 27	4	103
28 TL - 26 ms	1	1	62 TH - 28 ms	0.1	1	94 Volt Pulse - 28	3	77
29 TL - 27 ms	1	1	63 TH - 29 ms	0.1	1	95 Volt Pulse - 29	2	51
30 TL - 28 ms	1	1	64 TH - 30 ms	0.1	1	96 Volt Pulse - 30	1	26
31 TL - 29 ms	1	1	65 TH - 31 ms	0.1	1	97 Volt Pulse - 31	3.5	90
32 TL - 30 ms	1	1	66 TH - 32 ms	0.1	1	98 Volt Pulse - 32	5.5	141

Fig. 5. Excel Parameter file

4.1.1 Load parameter as per following sequence

- 1) Load '#' as Data ID for valid data confirmation while serial transmission (row1).
- 2) Load 'Pulse No' as total no of pulses to be generated (row2).
- 3) Load "Offtime" or TL data first. "Off time data" or "TL" is the delay between pulses. TL1 is the delay between external trigger and first pulse, TL2 is delay between first and second pulse and so on (row 3 to row 34).
- 4) After loading delay information for all 32 (TL1-TL32) pulses, start loading data for pulse width "On time data", TH. So the 33rd data (TH1) is the pulse width for the first pulse, 34th data (TH2) is the pulse width for the second pulse and so on till data for 32nd pulse width (TH32) (row 35 to row 66).
- 5) After loading pulse width for all the channels, start loading data for "Amplitude"(V). Thus 65th data is the amplitude information (V1), for the first pulse. 66th data is amplitude information (V2) for 2nd pulse and so on till data is loaded for all 32 pulses (V1-V32) (row67 to row 98).
- 6) Save Excel file as text file. Run Gas Puff_32.vi. It will ask for the file to transfer.
- 7) Load the text file, confirm the data and transfer via serial port as shown in the figure 6.
- 8) This data will be stored in controller RAM and on board serial EEPROM so even if supply is switched off, last loaded will be available. So once the data is loaded till next modification, data will remain stored in the on board EEPROM. The system, then wait for Trigger pulse. On receiving the trigger pulse, output is available on Output BNC as per the loaded data.

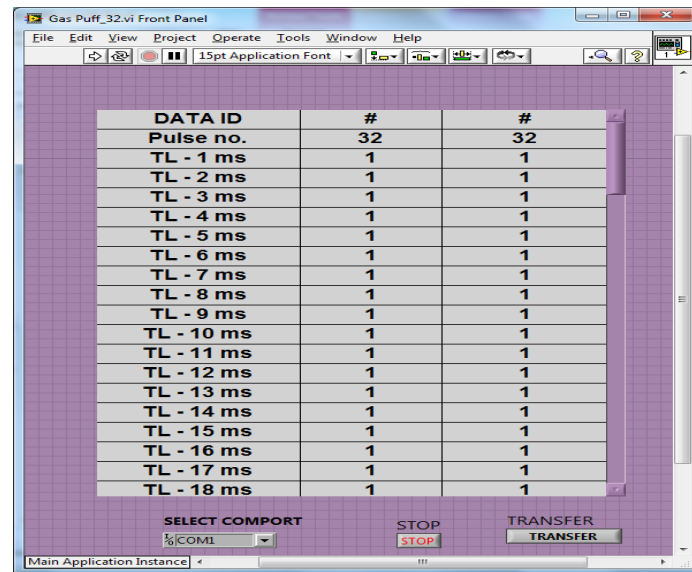


Fig. 6. Gas Puff_32.vi

Front Panel LED will glow when system power is switch 'On'. While transferring the parameter via serial port the front panel LED will be 'Off', indicating the transfer is going on. After transmission over, the LED will be 'On' again, indicating the system readiness for trigger.

AD558 is 8-bit, 0-10V digital to analog converter. The resolution is 39 mV. Actual input is converted using conversion factor $(\text{data} \times 1000) / 39$ and data is rounded off for one decimal point.

System works in two different modes: Manual trigger or External Trigger mode. The trigger input (TTL) is isolated from the enclosure and is applied using BNC connector. The manual trigger is using Push button switch.

4.2 Receiving the external trigger

To generate delay or low time, "TL loop" will be executed, while to generate width or high time "TH loop" will be executed. On receiving trigger either manually or from external trigger, TL 1 loop will be executed. Then V1 data will be loaded to DAC and TH1 loop will start executing. After TH 1 loop will be over, DAC will be reset. So output will be low. Output will remain low till TL 2 loop will finish execution. Again V2 data will be loaded to DAC and TH 2 loop will start execution and so on until all pulses will be generated according to loaded "pulse number".

5. Test Results

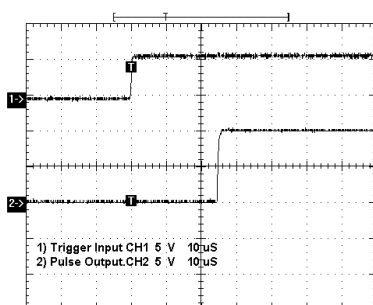


Fig. 7. Delay between Trigger & output 1st Pulse

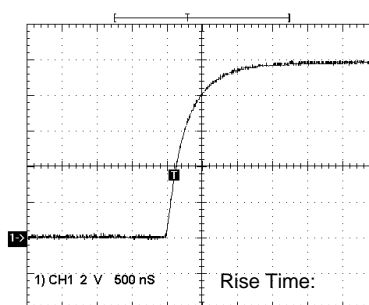


Fig. 8. Rise time of 900nsec

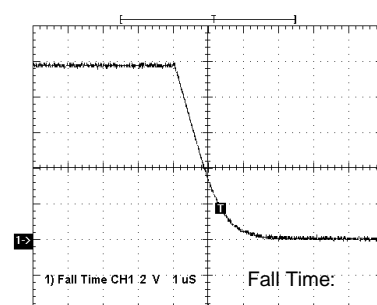


Fig. 9. Fall time of 800nsec

When $TL\ 1 = 0$, delay between trigger and output 1st Pulse is 26 μsec see the figure 7. The rise and fall time at any instance are 900nsec and 800nsec respectively, (figure 8 and figure 9).

6. Actual results

A typical recorded data of timing sequences during Aditya operation for 32 different pulse and for 10 different pulse output are shown figure 10 and 11.

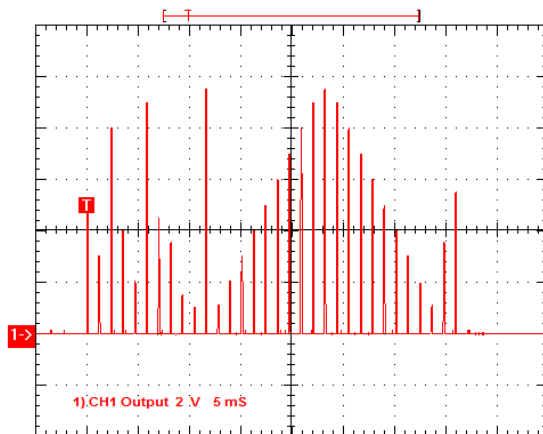


Fig. 10. Actual data for 32 pulses

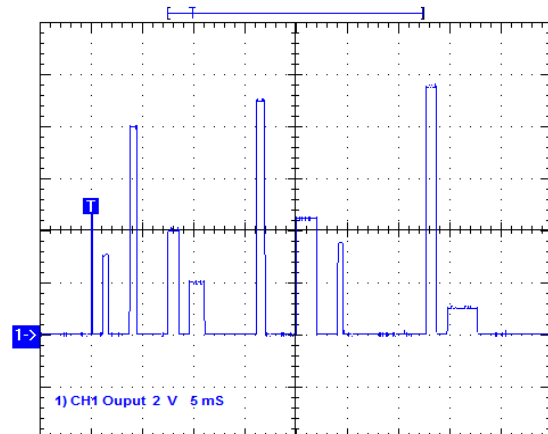


Fig. 11. Actual data for 10 pulses

The detailed parameter for figure10 is as shown in Excel file shown in the figure 5.

7. Conclusion

In house developed microcontroller based Programmable Pulse Generator is successfully working in gas puffing system in Aditya Tokamak. The CAMAC based controller system is replaced by developed stand alone system.

Acknowledgement

We would like to thank the members of Aditya Vacuum Group and Aditya Team for their support during the testing and implementation of the in house developed Programmable Pulse Generator.