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PSoC based signal generation for testing Fast response system for Eddy Current Flowmeter

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***Abstract*—Eddy current flowmeters are developed for measuring the sodium flow rate in the outlet of the primary sodium pump used in sodium cooled fast breeder reactor. A fast response system is developed for enhancing the measurement of Eddy current flowmeter in monitoring the flowrate. To characterize the performance of the developed system various types of test signals are generated which will resemble the actual signal from Eddy current flowmeter. This paper deals with the generation of the various types of such signals by direct digital synthesis method using Programmable system on chip microcontroller. In addition the performance of the developed fast response system was tested using the generated signals.**

***Keywords*—Direct digital synthesis,Eddy current, PSoC microcontroller,Signal generation**

I. Introduction

Signal generators generally have an electronic oscillator which are capable of creating repetitive waveforms such as sinusoidal, triangular, saw tooth, square etc.,. Modern devices use digital signal processors to synthesize such waveforms followed by digital to analog converter to produce the analog output. Arbitrary waveform generators (AWG) are another type of signal generators which produce arbitrary waveforms. AWGs are more expensive than simple signal generators and also have limited bandwidth.

Direct Digital Synthesizer (DDS) is a type of frequency synthesizer used for creating arbitrary waveforms by generating a time-varying signal in digital form by the use of phase accumulator, storing it in a ROM and then performing a digital-to-analog conversion. Following this the signal is passed through a filter for smoothing the generated signal [1,2,3]. DDS uses Taylor series method or lookup table for generation of signals [4,5] .DDS are superior over analog signal generators for their compactness and lower power consumption. DDS are manufactured using CMOS and FPGA implementation [6,7]. According to a survey conducted on DDS for generating sine wave, each method requires specific memory and significant additional circuitry [1]. In this paper a method for producing sine wave and arbitrary waves using PSoC microcontroller for a specific application is discussed that eliminates any additional circuitry required for the signal generation.

II. Description of Eddy current Flowmeter

The Eddycurrent flowmeter (ECFM) consists of one primary and two secondary coils placed symmetrically one in upstream side and other in downstream side of primary. The primary coil is excited by a constant current of 200mA with a frequency of 400Hz [8,9]. All the three coils are wound over the bobbin made of magnetic material and are encapsulated in stainless steel pocket to maintain physical separation of flowing fluid with primary and secondary coils. ECFM works on the principle of change in the magnetic field due to induced eddy currents as a result of sodium flow [8-14] .When ECFM sensor is placed in a pipe filled with static sodium and if primary coil is excited, then equal transformer voltage is generated in both the secondary because of equal flux linkage due to symmetry. If these two secondary coils are connected in phase opposition, the resultant output voltage is zero. If the primary excited ECFM is placed in flowing sodium, then voltage is induced in both the secondary due to motion of the flowing sodium in addition to the transformer voltage. The outputs of the ECFM secondary signals are sinusoidal in nature at a frequency of excitation (400Hz). Figure 1.0 shows the schematic of ECFM sensor.

$$S_2 = E_{trans} + E_{motion} \quad (1)$$
$$S_1 = E_{trans} - E_{motion} \quad (2)$$

E_{trans} represents the component of voltage due to transformer action and E_{motion} represents the component of voltage due to motion induced voltage [13,15]. Equation (1) and (2) represents the secondary voltages of ECFM sensor.

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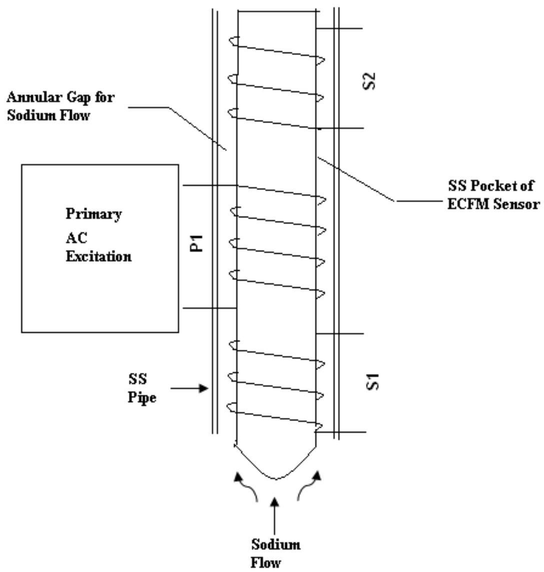

Figure 1 Schematic representation of ECFM

III. Description of Fast response system for ECFM

The fast response electronics has a signal conditioning unit, Programmable System on Chip (PSoC) microcontroller unit and display unit in addition to a graphical monitoring system [16,17]. Figure 2.0 shows the Block diagram representation of the developed fast response system for ECFM. The ECFM secondary voltage signals are processed by a Signal conditioning circuit.The signal conditioning unit has Instrumentation amplifier, Isolation amplifier, bandpass filter and True RMS to DC converter. Microcontroller acquires the signal from the signal conditioning circuit and process the signal for computing sodium velocity. The microcontroller unit has PSoC 3 processor whose hardware design includes 16 bit delta sigma ADC, Multiplexer, Timer, key module, LCD module and UART. In addition the microcontroller unit has decoder for the key interface.

IV. Design Requirement

The nature of ECFM signal is sinusoidal at a frequency of 400 Hz. The performance of the fast response system at each stage of the signal conditioning circuit can be determined by giving a sinusoidal signal at 400Hz.The actual signal from the ECFM sensor secondary coils are in the range of (0 to 100mV). So a variable voltage sinusoidal signal needs to be generated for testing the performance. Similarly the response time of the system can be identified by giving a burst of signal with varying amplitude. The following sections describes the generation of different types of signals using PSoC Microcontroller by the method of lookup table.

A. *Hardware Circuit Design*

The hardware consists of the PSoC 1 CY8C29466 processor and the 5 V power supply designed for powering the processor. Using programming the circuit is made to generate 2V signal. Figure 3.0 depicts the circuit diagram of the signal generator including PSoC processor. Since the original ECFM signal is in millivolts range, the generated 2V signal is fed to a potential divider arrangement which converts this 2V signal in to millivolts range. The output of the potential dividers provides voltage ranges between (0 to 198mV) and (0 to 360mV). These two signals that imitate the secondary voltages of ECFM sensors, is given to each channel of the signal.

B. *PSoC Microcontroller hardware design*

Figure 4.0 shows the hardware design of PSoC for generating the test signal. The PSoC microcontroller has programmable analog and digital blocks along with programmable interconnect which enable the user to do application specific design. This work uses 8 bit Digital to Analog Converter (DAC) and 16-bit timer for generating the test signal. An array of 24 values is created representing the phase value of the signal [18], as shown in equation (3). The signal should have a frequency of 400Hz; hence a timer of 104µs is configured to produce a frequency of 400Hz with 24 steps according to equation (4) & (5). The timer period is set according to the equation (6)

Step value = [128,161,192,218,238,251,254,251,238,218,192,161,128,95,64,38,18,5,0,5,18,38,64,95] (3)

Frequency = 24 × 400 = 9600 Hz; (4)

Time Base = 1/9600 = 104µs (5)

Time Period = Expected Time base ×Timer Clock (6)

Two switches are provided for selecting the type of test signals. Based on the selection, the generations of signal are made as per the algorithm described in section V.

V. Algorithm

A. *Main Program*

- Enable Global Interrupt
- Enable Timer
- Start Timer
- Start DAC
- Scan Switch 1 and 2
- Repeat the loop continuously

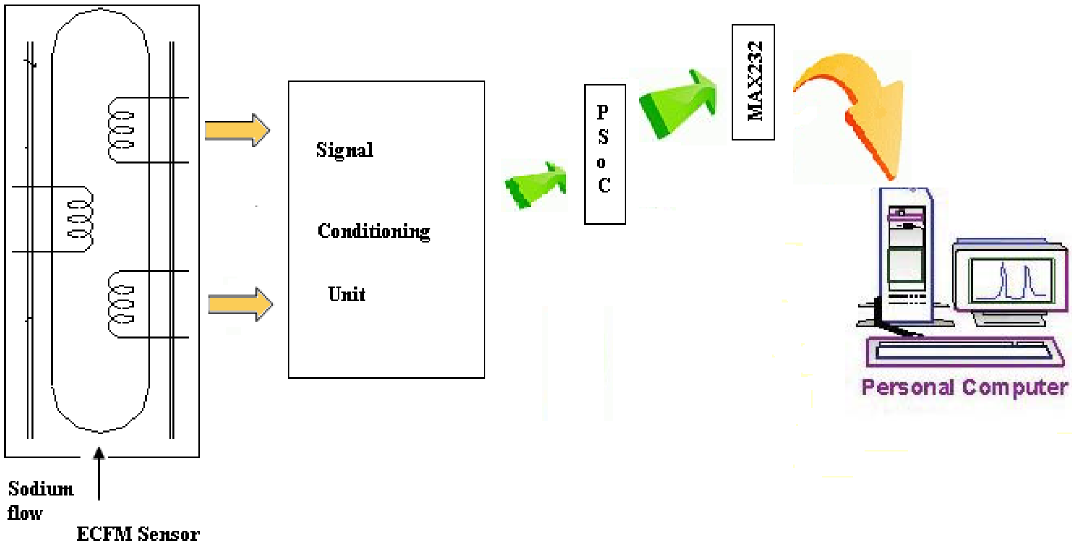

Figure 2 Block diagram of Fast Response System for ECFM

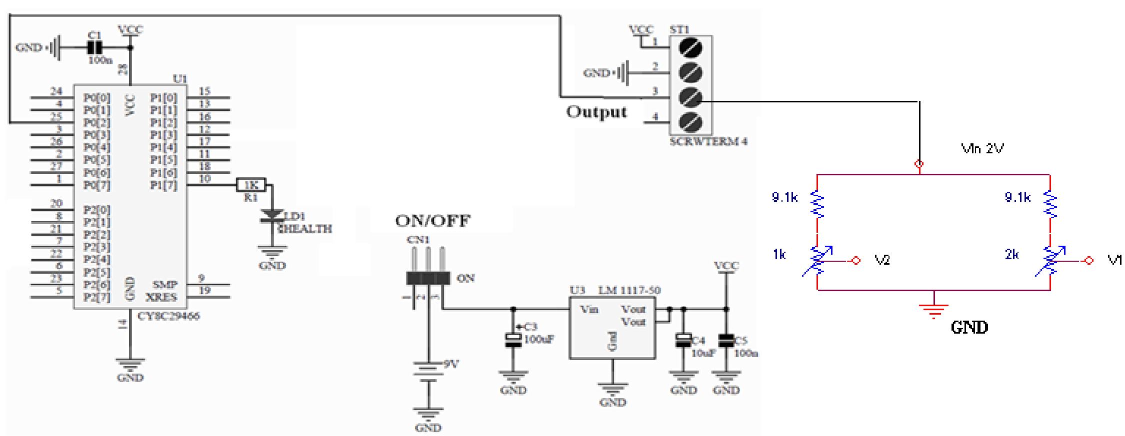

Figure 3 Connection diagram of Signal generator

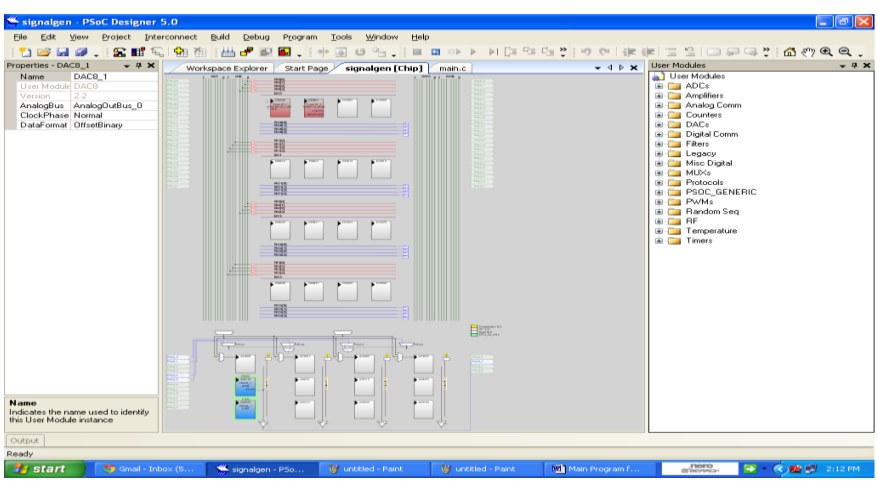

Figure 4 Screenshot of PSoC Designer

B. *Timer Interrupt service routine*

1) Generation of Sinusoidal signal (If Switch 1 and 2 is ON)

- Initialize array with 24 steps
- Write array value to DAC repeatedly

2) Generation of Sinusoidal Burst of signal (If Switch 1 or 2 is ON)

- For the period of 100ms, a value of 180 is passed to the DAC.
- For the period of next 100ms, the array value is passed.
- These two value are passed alternately

3) Generation of Square Burst of signal (If Switch 1 and 2 is OFF)

- For the period of 100ms, a value of 0 is passed to the DAC.
- For the period of next 100ms, a value of 254 is passed to the DAC.
- These two value are passed alternately

VI. Result and Discussion

Figure 5.0 shows the output of the generated sinusoidal signal. This signal is given to the signal conditioning unit and the output at each stage of the signal conditioning circuit is verified with the theoretical output. Figure 6.0 and 7.0 shows the response of the fast response system for the generated burst of sinusoidal signal and burst of square signal respectively. This depicts how fast the system respond to changes in the magnitude which enables us to predict the performance of the system for actual sodium flow in terms of rise time and settling time.

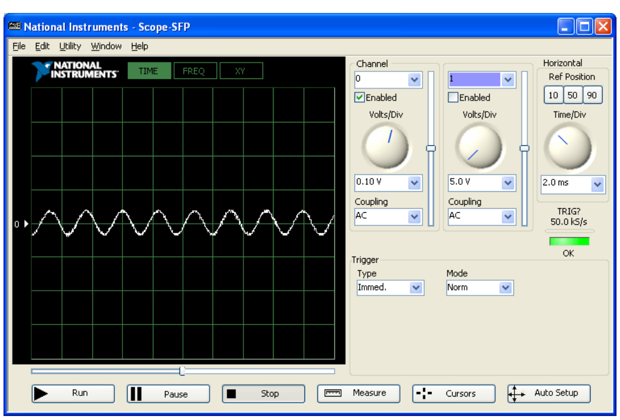

Figure 5 Generated Sinusoidal signal

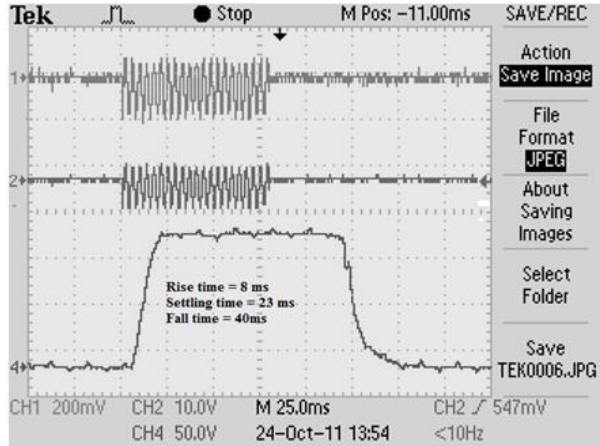

Figure 6 Response of Fast response system for Sinusoidal burst of signal

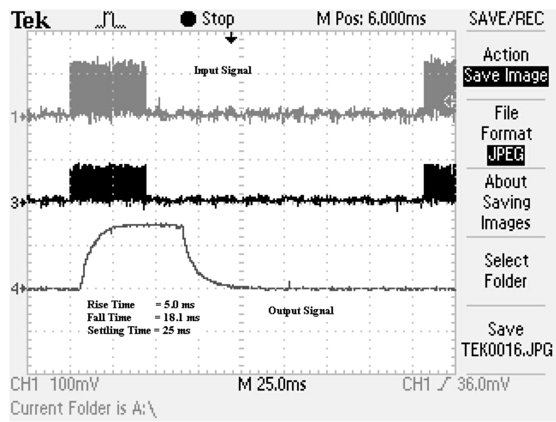

Figure 7 Response of Fast response system for Square burst of signal

VII. Conclusion

ECFM is developed for measuring the flow of sodium in the outlet of the fuel subassemblies in prototype fast breeder reactors. The fast response system developed for enhancing the performance of ECFM in monitoring the sodium flowrate involves PSoC microcontroller for its processing. The signal generated by the method of direct digital synthesis for testing the developed fast response system also use PSoC microcontroller for compatibility. The test signal thus generated is given to the developed fast response system and the output at each stage of the signal conditioning circuit is compared with the theoretical value and found to have close agreement. The signal generation can be refined by increasing the number of step value and with use of filter for smoothening.

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