

System on Chip (PSoC) Control for High Current Magnet Power Supply

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Abstract This paper describes a high current magnet power supply control through a Programmable System on Chip (PSoC) based embedded design and its menu driven control program written in Virtual instrument program. This design supports a wider dynamic range of current from 0 to 120 amperes in steps of 0.1 amps to the magnet power supply. It also has the fine tuning facility of current in the range of 0.01 amps to the magnet. In the existing BRUKER make B-CN-120 model power supply a programmable port has been implemented through which the PSoC embedded design interact via PCs USB port configured through Lab VIEW program resides in the PC. The successful PSoC design implementation simplifies the automation of BRUKER Magnet power supply.

Keywords: Programmable System on Chip, Virtual Instrumentation, Magnetic power supply

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1. Introduction

Power supply systems for superconducting magnets are usually low voltage, high current systems. Since most standard magnets have inductances of ten Henries or less, only one volt across the magnet will provide a minimum charge rate of 0.1 amperes per second or six amperes per minute. Operating currents for standard magnets are typically in the 60-150 ampere range so they can be charged to their rated fields in ten to fifteen minutes or less at one volt. "Bruker" make high current power supplies are employed in industry and particle physics research worldwide [1]. In systems employing magnets with high inductances, or where frequent decreases of the magnetic field are anticipated, a fast rampdown option in the PSoC embedded design and virtual instrument programming permits the magnet to be discharged properly. This is particularly important addition to large systems with high inductances which store hundreds of kilojoules of energy. In such cases, the time required to discharge the magnet at the end of the test might be a few minutes with the fast rampdown option, or exceed one hour without it.

2. Embedded Design

The new generation of re-configurable PSoC controllers, which integrates all the required digital, analog and digital communication components, will become the dominant system architecture compared to the other embedded systems, by employing advanced lithography and FLASH-based programming technology. This architecture makes it

possible for the designer to create customized peripheral configurations for the requirements of any specific application.

This paper describes an embedded design implementation in PSoC and graphical user interface (GUI) menu driven automation program to control current in the BRUKER make B-CN-120 model high current power supply used for superconducting magnets in Low temperature measurements. The magnet power supply for superconductivity coil requires fast dynamic performance of di/dt and smooth changeover of current direction. To meet these specifications, high performance PSoC-based controller is designed for the existing BRUKER magnet power supply, by implementing a programmable port through which the PSoC embedded design interact via PCs USB port configured through Lab VIEW menu driven program resides in the PC.

3. Programmable System on Chip (PSoC)

Programmable System on Chip (*PSoC*) is a unique microcontroller from Cypress Microsystems. It features digital, analog and digital communication blocks, which themselves allow implementation of large number of required peripherals. PSoC is mixed-signal arrays consists of several sub systems on a single chip. In order to develop the embedded application that works on these chips and provide solution to all the stated problems, Cypress Microsystems offers PSoC Designer tool [2]. It is not only about combining software development environment with an intuitive graphical design editor, but also enabling immediate testing of new ideas, rapid response to hardware changes, creating libraries of sharable design elements, custom peripherals, error-free

interaction with the peripherals on-chip, and complete design realization using the built-in debugger [3]. In short

the functioning and usage of PSoC designer tool can be divided into 4 steps as shown in Figure 1.

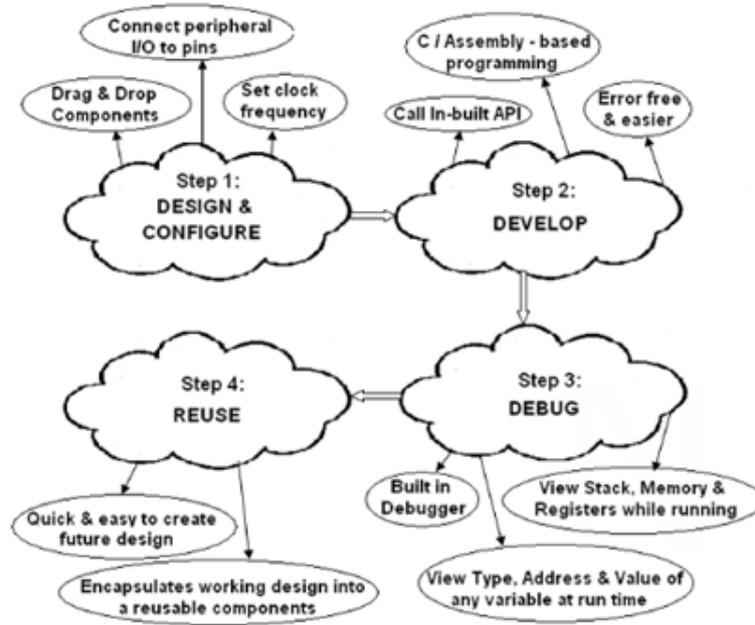


Figure 1. Steps to create project using PSoC Designer [4]

4. Graphical Language-Lab VIEW

Lab VIEW is a graphical language package based on virtual instrument (VI) programming technique commonly used with hardware acquisition boards has many features for data acquisition and processing of either measured data

or simulated signals. A program written in Lab VIEW uses dataflow programming. Every Lab VIEW program has a user interface where the user can enter data for the program to process and output that the program has generated and it has a set of code that indicates that processing is to take place [5].

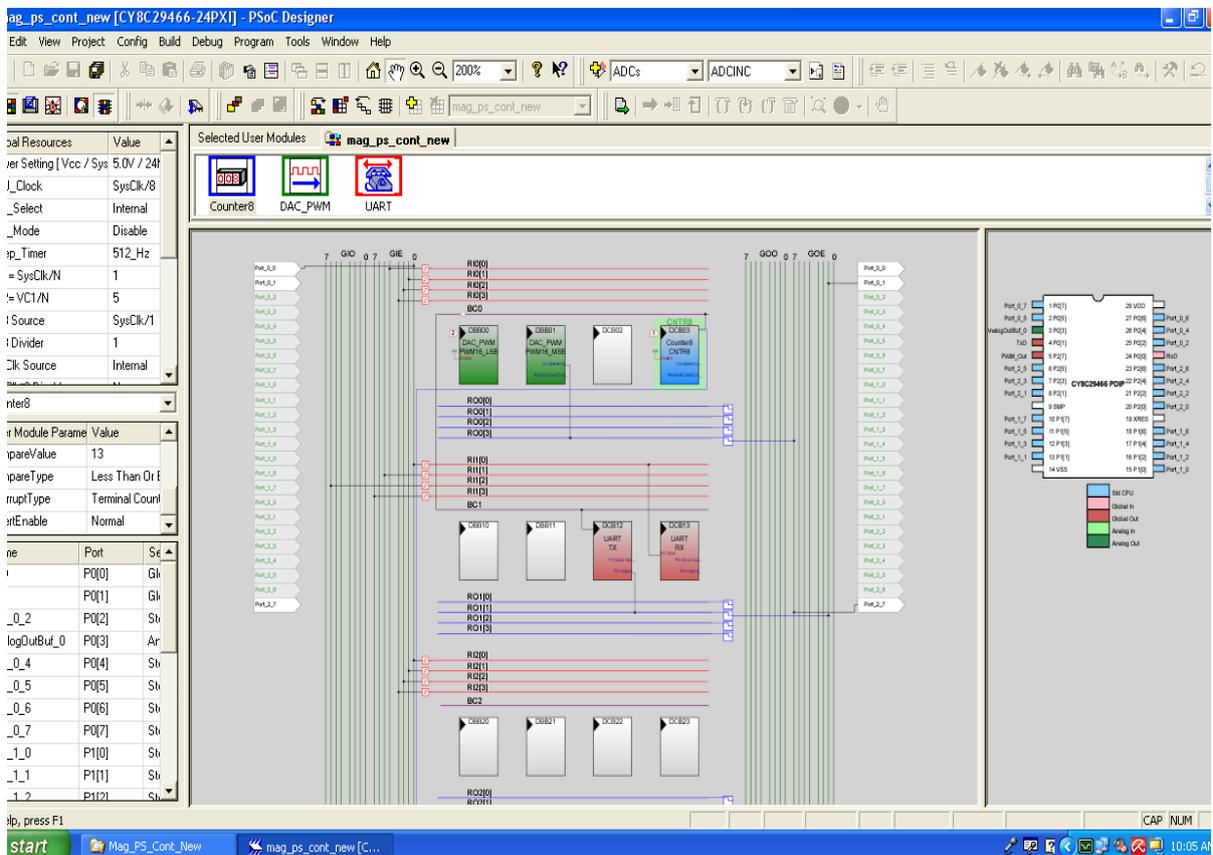


Figure 2. PSoC Designer Screen for Magnet Power supply Automation

5. Methodology

5.1. Implementation Using PSoC High Current Magnetic Power Supply

BRUKER Magnet power supply model B-CN-120, Embedded PSoC design and *virtual instrument* menu driven program written in Lab VIEW has been implemented. In the existing BRUKER high current magnet power supply [6,7], a programmable port has been created from the front panel rotary current control switch to programmatically control the system as per the user choice. The current can be adjustable between 0 and 120 amps with a resolution as small as 0.1 amps as well as 0.01 amps. An Embedded design implementation in PSoC using a programmable 14 bit Pulse width modulated DAC for controlling the magnet current and a 14 bit ADC module implementation for sensing the magnet current has been carried out. A graphical user interface *virtual instrument* (VI) control program written in Lab VIEW interacts with the PSoC interface through PC's USB port, which will in turn control the magnet current through its programmable port created in the power supply unit, senses and controls the magnet power supply current as

per the user set value. Figure 2 shows the implementation of 24 bit PWM, Clock divider and UART user modules in the PSoC designer screen for the magnet power supply control application requirement.

A pulse width modulator (PWM) has a variable pulse width, where the width of the pulse can be varied from 0 to 100% of its period. In the PSoC, a conventional PWM has a simple down counter and a compare register. When the value in the count register is less than or equal to the Compare register the compare output goes high. The pulse width of the PWM can be varied by changing the value in the compare register. The relationship between the PWM's operating frequency, its resolution, and the clock frequency F , is defined as: $\text{PWM frequency} = F/2N$, where 'N' is the number of stages in the PWM counter chain and is also the resolution of the PWM in bits. $F = 48 \text{ MHz}$, $2N = 32,767$, HEX 0000 7FFF, the 2930 Hz 14-bit PWM [8].

To get the smooth DC voltage proportional to the duty cycle of the PWM to function as a 14 bit DAC [9], a low-pass filter has been implemented with discrete RC value which can smooth PWM out pulses. This can generally be in the form of a simple RC filter $C = 47 \mu\text{F}$ $R = 1 \text{ K}$.

5.2. Virtual Instrument Programming for Magnet Power Supply Using Lab VIEW

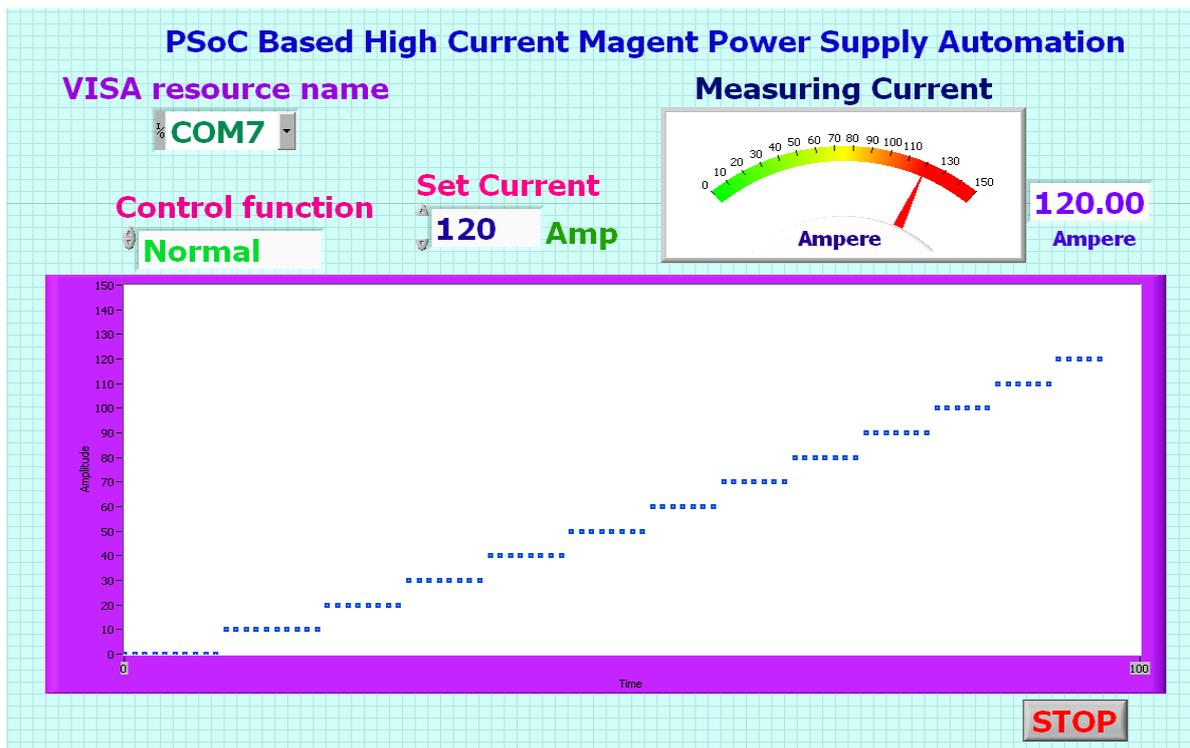


Figure 3. Virtual Instrument Programming in Lab VIEW Front panel GUI for Magnet Power Supply Automation

The BRUKER B-CN-120 model Superconducting Magnet Power Supply is an advanced instrument designed specifically for powering superconducting magnets. This supply is capable of delivering up to ± 1 volts of output voltage and up to 120 amps of output current, depending on the requirement [10,11,12]. Power supplies used for energizing superconducting magnets have unique requirements placed upon them. The supplies are used to source energy to magnets which can have a wide range of inductance (mH to thousands of henries). In addition, the magnet load can range from a nearly pure resistance to a

nearly pure. The quiet switch-mode design of the CS-4 makes it a low noise, highly efficient supply – and one that is proven stable even on the most sensitive superconducting magnets. Versatile programmability within the PSoC allows the user to specify several different sweep rates for different current ranges of the magnet – making it possible to sweep a magnet slower in a particular range as per user requirement through menu driven program. A menu driven GUI control program shown in Figure 3 provides the user to set and measure the current. The PSoC implementation of BRUKER high

current magnet power supply system presents a new methodology to approach for high current power supply solutions using PSoC. Its simplicity and effectiveness makes it suitable for fast prototyping and low cost solutions [13,14,15].

6. Results and Discussion

The embedded design has been tested for its functionality with the BRUKER high current magnet power supply and found that very accurate setting and sensing of magnet current has been achieved.

PSoC based embedded design successfully designed fabricated and tested with the BRUKER Magnet power supply.

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