Chapter 6

Enhancement of ARM Cortex – M Architecture using Cypress PSoC

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6.1 Introduction To PSoC5 Development Board:

ARM core is being enhanced by different vendors; Cypress semiconductor used ARM Cortex M core in CY8CKIT001 development kit which consists of PSoC CY8C55 (PSoC5) family processor module as one of the option. PSoC development board offers various hardware facilities like LCD display, small bread board, LED’s, Cap Sense surface, wireless port, Serial port, USB port, ON/OFF switch and various jumpers are available for development of various application on board itself. Figure 6.1 shows the PSoC development board kit[29]. Further the CPU module of various versions of PSoC like PSoC1, PSoC3 and PSoC5 can be embed with the same development board.

![Figure 6.1 PSoC 5 Development Board](image)

In the PSoC Processor Module Socket PSoC5 IC is to be inserted which is CY8C55 family processor module – which comprises the ARM Cortex-M3 Processor inside it. PSoC5 comprises 32-bit ARM Cortex M3 core running at 80MHz with integrated USB device support, analog and digital blocks, and in-system debugging capabilities.
6.2 Hardware of PSoC5:

The PSoC5[27] core includes a CPU, memory, clocks, and configurable GPIO (General purpose IO) maximum GPIO is up to 72 (all are configurable with any analog or digital peripherals). The PSoC 5 series of controller having ARM CPU core with speeds up to 80 MHz.

The memory includes
- 256 KB of Flash memory for program memory
- 64K bytes of SRAM for data storage and
- 2KB of EEPROM memory

PSoC5 consists of ARM Cortex – M3 as its CPU building blocks and architecture of ARM Cortex M3[2][27] is shown in Figure 6.2

![Figure 6.2 ARM Cortex M3 Block Diagram](image)

The hardware of PSoC chip is programmable as per the user requirement. It can also have programmable interconnects digital and analog hardware configuration. The PSoC family consists of many mixed-signal modules with
on chip ARM controller devices. The analog and digital hardware blocks can be configured by PSoC creator software tool from Cypress itself. It is having microcontroller core with configurable hardware on a single chip. The included analog and digital blocks can be control through programming instruction of the device. One can use mixed signal system configuration for on chip solution.

**Figure 6.3 Block Diagram Of PSoC-5 Device**

As shown in block diagram[27] of PSoC-5 series device in Figure 6.3, the PSoC-5 device has programmable peripheral elements like analog blocks i.e. amplifiers, ADCs, DACs, Filters, cap-sense and comparators, and digital peripheral such as timers, counters, PWMs etc. Also, there is provision for
communication peripheral module like I2C, SPI and UART protocols. In addition to these analog and digital peripheral, PSoC devices include on chip ARM microcontroller core with 32-bit accumulator, power and sleep monitoring circuits, RTC (Real Time Clock) and display modules like LCDs, seven segments software modules.

6.2.1 Digital Sub-system On PSoC5:
The digital sub-system block diagram[27] of PSoC-5 is shown in Figure 6.4, the digital blocks contains Universal Digital Block (UDB) arrays, DSI routing interface, digital core system and fixed function peripherals.

6.2.2 Analog Sub-system on PSoC5:
The analog peripherals on PSoC-5 are very flexible and can be configured to design specific analog system applications. As shown in Figure 6.5 for analog peripherals[27] on PSoC is can be interfaced with programmable interconnects to have analog system design.
In addition to ADCs and DACs, the analog subsystem provides DFB (Digital Filter Blocks) which can perform the task of MAC (Multiply and Accumulate) of 48-bit in one clock cycle. Apart from that, it also consists of Comparators, OPAMPs, and configurable switched capacitors. Analog interconnect of various analog modules like:

- Filter
- Comparators
- ADCs
- DACs
- Cap-sense
- Switched Capacitor and others

With

- Power supply
- Various GPIOs

Is shown in Figure 6.6.
6.2.3 Communication Resources:
There is also facility to configure the various communication protocols in PSoC for data communication with the other system modules. The selected protocols from the communication user module block one can incorporate into the design. The various communication[27] user modules are listed here.
- Up to 2 Full-Duplex UARTs
- Multiple SPI Master or Slave
- I2C protocols
- USB interface
- One wire communication etc.

The PSoC5 configuration and programming is done on PSoC creator software tool from cypress. The PSoC creator software tools discussion is in the following subsection.

6.3 PSoC Creator Software Tool:

PSoC creator[28] is a Microsoft ® Widows-based, integrated development environment (IDE) for the programmable System-on-Chip (PSoC-5) devices from cypress. The PSoC creator supports a high-level C language compiler for specific device of PSoC series. The required digital and analog system blocks and components like PGA (Programmable Gain Amplifier), ADC, UART and LCD are initially configured. After the configuration of the system blocks, the configured system blocks in the PSoC are turned on through API (Application Programming Interface) functions. The PSoC device configuration of various blocks through PSoC creator software is discussed below. This software also facilitates user for develop programming of design module in C as well as in assembly level language. The following steps describe about the working with PSoC creator software for project system design using PSoC chip.

**Step 1:** Initially for creation of new project click on New Project wizard in to the project option of the tool bar. Successively the software ask for various options of setting for project like project name, location in the directory, device ID, C or Assembly programming etc. The screen shot of project creation is shown in Figure 6.7.
Figure 6.7 Screen shot of PSoC-5 Project Creation in PSoC Creator

Step 2: After creating project – bring the module/device from component catalog to the design space (drag and drop). Same is shown in Figure 6.8 where PGA (Programmable Gain Amplifier) brought into design space.

Figure 6.8 Component Placement
Step 3: After placing PGA block into the project folder environment click on the property window and set the property of added PGA block like gain, supply etc as shown in Figure 6.9.

![Configuration of Module Properties](image)

**Figure 6.9 Configuration Of Module Properties**

For further details of block/module that is placed, one can also open the datasheet of the respective module by right clicking on module name and choosing datasheet tab. In the data sheet of the respective block one can also, study the sample code of the programming in C and assembly language programming is given. At the end one can program the module which is configured and generate the hex binary file to be downloaded into PSoC-5 chip by build project tab from the toolbar option.

Step 4: After placement of analog and digital components and routing of all connections with various peripherals (as shown in Figure 6.10) we have to build the PSoC-5 configuration for executable program code. If the configuration is true then PSoC creator build option will give build succeed with no error and the code for PSoC-5 ARM is ready to installed on actual
hardware. The building of application developed for real time temperature monitoring is shown in Figure 6.11.

Figure 6.10 Routing Of All Analog and Digital Blocks

Figure 6.11 Screen shot Of Project Build In PSoC5
6.4 Application Development On PSoC5:

Programmable System on Chip (PSoC) IC from Cypress Semiconductor is well suited for portable embedded systems that require a great amount of low power consumption and small in size. Since the PSoC having capability of configuring analog and digital programmable hardware blocks as and when required, one can configure it dynamically by software routines and so, power consumption can be controlled.

Real-time monitoring[25] of various parameters are really essential for biomedical analysis and to avoid catastrophic action in industry. Parameters can be Temperature, Pressure, Speed, Flow etc; which needs to track for the smooth conduction and at times for taking corrective measures. Mainly design involves selection of the sensors, signal conditioning, A to D conversion and display and monitoring of the data on the central computer.

I propose a design[24] of real-time temperature monitoring and data logging based on PSoC5 with ARM Cortex-M3 core. Design usually required interfacing different analog and digital block which requires multiple chips and their power, speed issues. PSoC5 gives a single chip solution with selectable modules controls the on/off of the module and thereby power efficient. Apart from that system is more reliable and gives flexibility of design. The same design can be duplicated for other parameters like pressure, flow, speed etc; even for multiple sensors and data acquisition systems[26].

6.5 Hardware Design Of The System:

The temperature measurement system requires a transducer to convert temperature into an electrical signal. There are different kinds of temperature sensors available we are using LM35 it can be easily replaced by the different sensor as per the need of the application. The sensor module is connected with prototyping breadboard of the development kit.

The block diagram of the system is shown in Figure 6.12. It is consisting of sensor module, the output of the sensor module is directly connected to (PSoC5 selectable) signal conditioning, and an amplified signal is then converted to digital format with help of ADC (sigma delta).
The converted digital data is processed by the ARM cortex M3 core. The processed output equivalent to the temperature is given to display and also made available to central computer through USB-UART converter. The hardware setup is shown in Figure 6.13.
The tool which is used to work with PSoC5 is PSoC Creator which provides IDE for the Cypress make PSoC. The actual hardware is to be selected from the available modules and top diagram schematic is developed. System schematic is shown in Figure 6.14. For individual block like PGA, ADC etc; parameter setting is to be done as per the requirement. Once the parameters set the module behaves as per the properties set in the module. Here for the design pin 1 is connected with the output of the temperature sensor and pin 2 is connected with the ground for the reference of inverting amplified.

![Figure 6.14 Hardware Design Schematic](image)

After the schematic is prepared – pin assignment is to be done, this pin assignment will actually map the input output of the system with the pins of ARM core.

### 6.6 Firmware Of The System:

The firmware for the system is implemented on PSoC5 using ARM Cortex-M3 controller programming instruction set. The components required in the system must be configured first by the software initialization by the various parameters passing and calling appropriate routine. The selected block must be turn on by activating power source which is controlled through instructions.
The firmware starts with initializations of the PSoC5 digital and analog block. After initialization of the block the individual component is required to make powered, which is done through PSoC API functions. The algorithm continuously checked whether data available from ADC output. If data are available from the ADC data are displayed on the LCD display.

The acquired data is transmitted through a USB to UART converter module interface to PC. The data received on pc can be captured on GUI based terminal software which is available as open source. The baud rate for UART module in the PSoC is set to 9600 bps and one stop bit. However the baud rate can be change for other setting requirement in the PSoC UART module. The received data on pc can be stored in a file for data recording. The screen shot of the terminal software is shown in Figure 6.16.
The received data recorded in a log file can be used for history analysis and to take corrective measures. Figure 6.17 shows the log file for terminal which indicates the data recorded for a period of time.

![Screen shot Of Terminal Log File.](image-url)
6.7 Enhancement Of PSoC-5 ARM Architecture:

As we have discussed about enhancement feature of ARM architecture earlier. In this PSoC-5 ARM architecture there is a programmable capability of various peripherals like analog block, digital block and various mixed signal peripherals into ARM core. For example we can implement example of ADC interfacing with any signal conditioning circuits to convert data and send to the ARM architecture core, so that we can enhance the feature of mixed signal circuitry into ARM core.

Digital block can also be implemented to enhance the features of digital architecture of ARM core in PSoC-5. In this example[27] we have tested LCD implementation for digital data display with ARM core. Also, the communication facility of ARM architecture can be enhanced in PSoC-5 ARM core. Many such communication peripherals like UART, I2C, SPI, USB, two wire communication etc; in this application we have tested UART facility of PSoC-5 ARM core. As shown in Figure 6.18 various block configurations can be implemented.

![Figure 6.18 PSoC-5 ARM Architecture Enhancement](image-url)

Figure 6.18 PSoC-5 ARM Architecture Enhancement
One can interface latest technology for touch screen based interface with PSoC-5 ARM Architecture. One such example is tested on PSoC-5 as discussed below.

In PSoC-5 ARM architecture Cap-Sense Module is available by which you can include the configuration module to the ARM core and program it for sensitive capacitive touch sensing facility. In this example as shown in Figure 6.19 the cap sense block placed along with LCD display and two LED’s interfacing for showing the status of whether touch is being made of not. In this tested example when we touched the Cap-sense button the status of touch position is displayed on LCD and respective LED blink is observed. The configuration of Cap-sense and various other modules are placed in PSoC creator software to enhance the feature of ARM core in such advancement in technology.

![Figure 6.19 Cap-Sense Testing With PSoC-5](image)

The CapSense button and slider state is displayed on the character LCD. Digital pins LED1 and LED2 are used to light up an LED based on whether its corresponding button is touched.
6.8 Summary And Discussion:

Enhancing the ARM architecture feature in Programmable Logic Devices like PSoC5 is well suited and easily configurable analog and digital blocks. The requirement of today’s system on chip concept demands the ARM architecture which is having dynamically configurable devices, thereby saving enormous amount power in overall system.

This chapter talks about the enhancing mechanism of mixed signal requirement, by implementing real time temperature monitoring system. By incorporating LCD module in PSoC5 one can enhance the feature of digital block. At the end one can say the ARM Cortex M3 architecture feature can be enhanced by incorporating programmable logic supported by PSoC5 series of Cypress semiconductor.