
Using PIC16F Microcontrollers for System Power Supply Control

Introduction

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Modern process computers, commonly based on high-end 32- or 64-bit microprocessors, provide developers with significant options in terms of operating system use. However, their high processing power is paid for with equally high-power demand, which can be a problem in battery-operated real-time applications. Using a simple low-power and cost-effective 8-bit PIC microcontroller as the secondary device provides a convenient and cost-effective means of controlling the system power state. This discussion will consider the use of PIC16F microcontrollers in that role.

This application note demonstrates the use of the PIC16F15244 microcontroller in such applications for system power supply control. As a case study, for the demonstration, a reference application based on a Raspberry Pi® Single Board Computer (SBC) is used as the process computer (host) and a PIC16F15244 Curiosity Nano Evaluation Kit as a power supply control module (client). Additionally, the SBC functionality is also emulated with another PIC16F15244 microcontroller, as one of the use cases discussed in the application note. Sections [3.6 Process Computer Firmware Overview](#) and [3.7 Supply Control Module Firmware Overview](#) describe the process computer and supply control module firmware developed using the PIC16F15244 microcontroller and PIC16F15244 Curiosity Nano Evaluation kit. The PIC16F15245 microcontroller-based supply control board hardware design files are provided in supplemental files; links to these files are provided on the device product page on the Microchip web site. The application firmware is available as GitHub projects; direct links to the GitHub repositories are provided in the document.

Features

This application note features:

- System power control using the PIC16F15244 family of microcontrollers
- System power supply control application emulation using the PIC16F15244 Curiosity Nano Evaluation Kit
- Power consumption data analysis
- System power supply control application demo with the Raspberry Pi and the PIC16F15245 Control Board (see Section 6. [Appendix: System Power Supply Control for the Raspberry Pi Application](#) for a complete description)

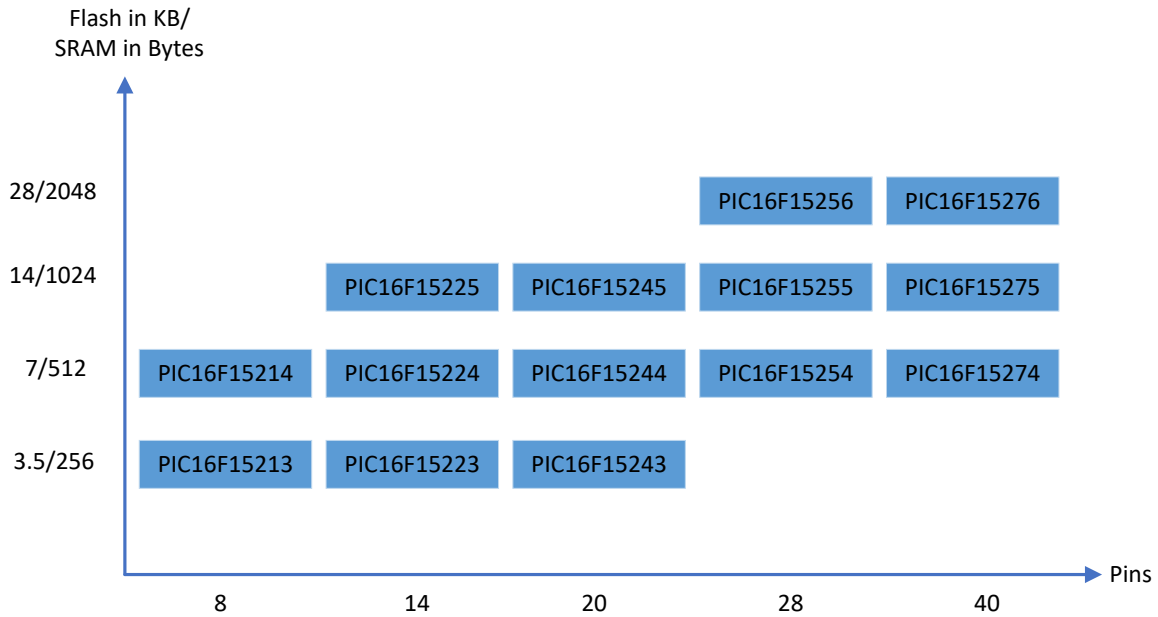
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1. Relevant Devices

PIC16F15244 family products are available in 8/14/16/20/28/40/44-pin packages for cost-sensitive sensor and real-time control applications. The PIC16F15244 family of microcontrollers offers up to 28 KB of Flash memory and up to 2 KB of SRAM. This microcontroller family also provides additional memory features, such as a Memory Access Partition (MAP), to support users in data protection and bootloader applications, and a Device Information Area (DIA), which stores Fixed Voltage Reference (FVR) offset values to help improve ADC accuracy. PIC16F15244 family devices also offer a rich set of core features, power-saving functionality, and both digital and analog peripherals.

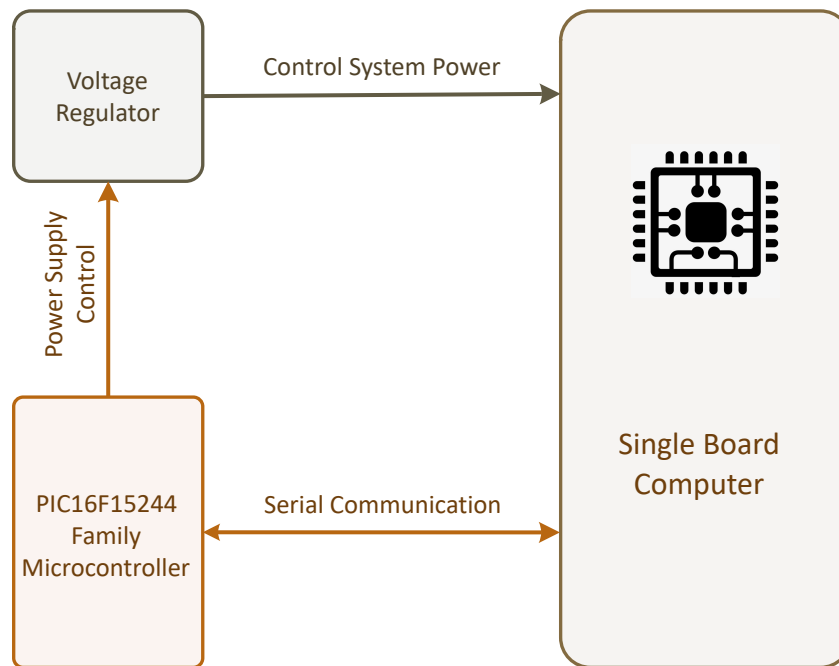
Figure 1-1. Overview of PIC16F15244 Family of Microcontrollers



2. Usage of PIC16F15244 Family of Microcontrollers for System Power Supply Control

Consider a high-end application developed on the Raspberry Pi Single-Board Computer (SBC). The SBC consumes plenty of power when active, and may not be needed at all times. In order to save maximum power, the power supply to the entire SBC should be cut OFF, instead of just shutting down the CPU. To perform this action, a PIC16F15244 family microcontroller is used as a secondary microcontroller in the system to turn OFF and ON the SBC power using the voltage regulator. After turning OFF the voltage regulator, the microcontroller can enter Sleep mode to further reduce the system power consumption.

Figure 2-1. System Power Supply Control Using the PIC16F15244 Family of Microcontrollers



(As previously discussed, the power control system may be realized with any 8-bit PIC microcontroller.)

There are numerous possibilities when to turn the regulator ON or OFF. For example, an intelligent host can give a command to the client to switch the power OFF and for how long it should stay OFF. User interface-based turn ON and OFF are also possible. An example of this is wake-up on touch. The application can thus be extended in multiple possible ways. One such use case is discussed in this application note.

3. System Power Supply Control Emulation with the PIC16F15244 Microcontroller

To demonstrate the system power supply control application, two PIC16F15244 Curiosity Nano Evaluation Kits are used: one acts as the host and the other as the client. The host (referred to from this point as the “process computer”) emulates the Raspberry Pi-based SBC functionality. The client (referred to as the “supply control module”) turns the regulator ON or OFF; this is emulated by the on-board LED.

Refer to Section 6. [Appendix: System Power Supply Control for the Raspberry Pi Application](#) for an implementation and demonstration based on a Raspberry Pi board.

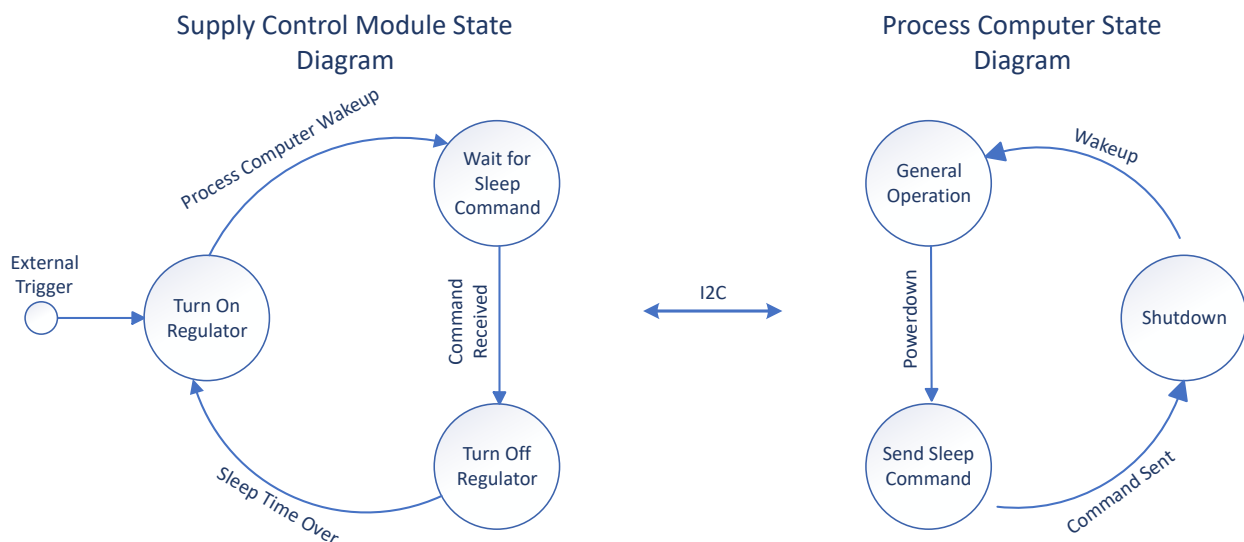
3.1 Application Overview

To implement the emulated system power supply and its control, a simple application is developed using two PIC16F15244 Curiosity Nano Evaluation Kits. The process computer sends out a command to the supply control module over an I²C bus to shut down the system power. This sleep command contains the duration for which the system is to be put in Low Power mode. For simplicity, the on-board switch on the process computer (i.e., the PIC16F15244 Curiosity Nano kit emulating the process computer) is used to trigger the power-down command.

After receiving the sleep commands, the supply control module waits for 30 seconds before turning OFF the regulator. This period provides sufficient time for the process computer to perform the shutdown housekeeping tasks that are required for Linux[®] OS-like operating systems (such as invoking the shutdown procedure). The supply control module device disables the emulated voltage regulator, then enters Sleep mode. The supply control module will automatically turn ON the voltage regulator after the power-down period expires or an external trigger is provided.

[Figure 3-1](#) demonstrates the operation of the process computer and supply control module.

Figure 3-1. Application State Diagram for Process Computer and Supply Control Module Firmware



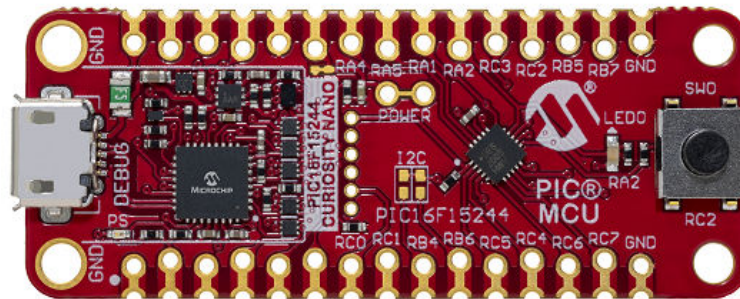
Power-Down Command: The power-down command triggers the shutdown of the regulator by the supply control module’s microcontroller. The command also contains the time duration the system will be turned OFF. The command consists of an ASCII string for cross platform support: *S (number of seconds)*, where the first byte is the character ‘S’ and the following six characters are the shutdown duration in seconds (for example, ‘S007200’ represents 7200 seconds, or two hours, of system power-down).

Manual Wake-Up Interrupt: In case the process computer needs to be turned ON before the power-down period is over, the supply control module can also accept user input. To demonstrate this feature, an on-board switch is used on the Curiosity Nano board serving as the supply controller is used. The supply control will immediately turn ON the regulator in the event of a switch press.

3.2 PIC16F15244 Curiosity Nano Evaluation Kit

The PIC16F15244 Curiosity Nano Evaluation Kit is a hardware platform aimed at evaluating the peripheral features of the PIC16F15244 family of microcontrollers. The Curiosity Nano series evaluation kits include an on-board programmer and debugger. No external tools are necessary to program and debug the PIC16F15244 microcontroller, which makes it an ideal hardware platform to use for demonstrating this application. The board is powered through the USB port via the micro-B USB cable.

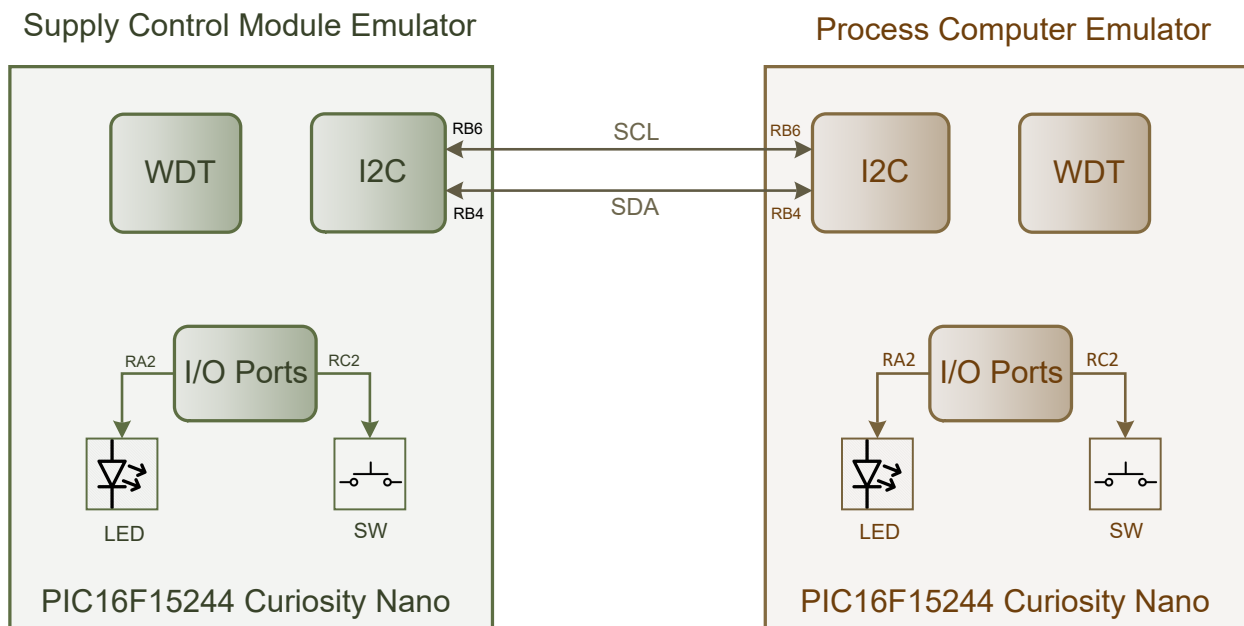
Figure 3-2. PIC16F15244 Curiosity Nano Evaluation Kit



3.3 Hardware Setup

Figure 3-3 shows the hardware connections of the PIC16F15244 Curiosity Nano-based emulation for system power supply control.

Figure 3-3. Hardware Connection Diagram



Note: Required external pull-up resistors for the SDA and SCL lines are incorporated on the Process Computer board. The pull-up resistors are usually added on the host MCU board, and are not required on client board.

3.4 Microcontroller Pin Configuration Details

Table 3-1 and Table 3-2 give the pin configuration details of the host (process computer) and client (supply control module) PIC16F15244 Curiosity Nano evaluation kits.

Table 3-1. Host (Process Computer) Microcontroller Pin Configuration

Microcontroller Pin	Signal Name	Signal Description	Pin Direction
RC2	Switch	Power Down Command	IN
RB4	SDA	I ² C Serial Data	IN/OUT
RB6	SCL	I ² C Serial Clock	IN/OUT

Table 3-2. Client (Supply Control Module) Microcontroller Pin Configuration

Microcontroller Pin	Signal Name	Signal Description	Pin Direction
RC2	Switch	Manual Wake-Up	IN
RA2	LED	Voltage Regulator	OUT
RB4	SDA	I ² C Serial Data	IN/OUT
RB6	SCL	I ² C Serial Clock	IN/OUT

3.5 PIC16F15244 Microcontroller Firmware

The system power supply control application includes two sets of firmware, one for the process computer and one for the supply control module. As detailed in the previous sections, PIC16F15244 Curiosity Nano kits are used to emulate both the host (process computer) and client (supply control module). The firmware for both boards is created using the following development environment:

- MPLAB® X Integrated Development Environment (IDE) v5.50
- MPLAB Code Configurator (MCC) v5.0.3
- XC8 Compiler v2.32
- Master Synchronous Serial Port (MSSP) MCC Melody driver v6.1.0
- Timer0 (TMR0) MCC Melody driver v4.0.7



AN4121: Process Computer Firmware

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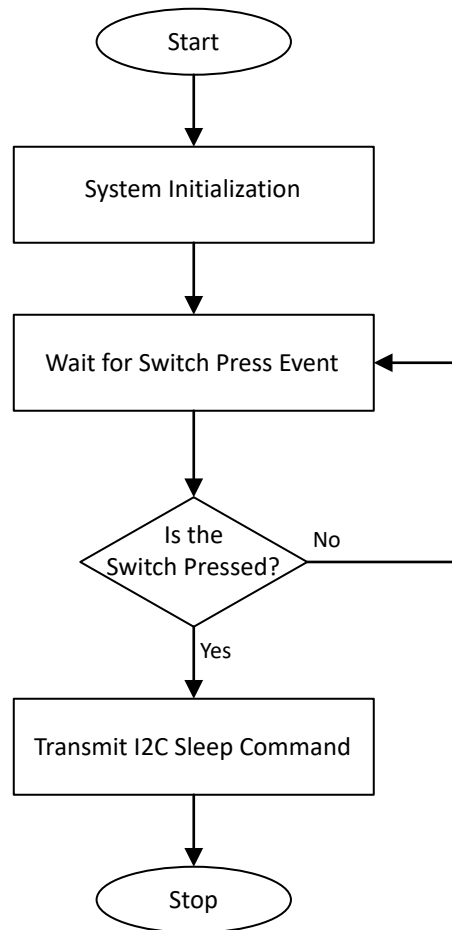
AN4121: Supply Control Module Firmware

[Click to browse repositories](#)

3.6 Process Computer Firmware Overview

The process computer-side firmware for the system power supply control demo is developed to emulate the power-down feature of the process computer. As detailed in section 3.1. [Application Overview](#), the computer will send out a power-down command when a switch press event is detected. [Figure 3-4](#) shows the detailed firmware implementation methodology.

Figure 3-4. System Power Supply Control - Process Computer Firmware Flow Diagram

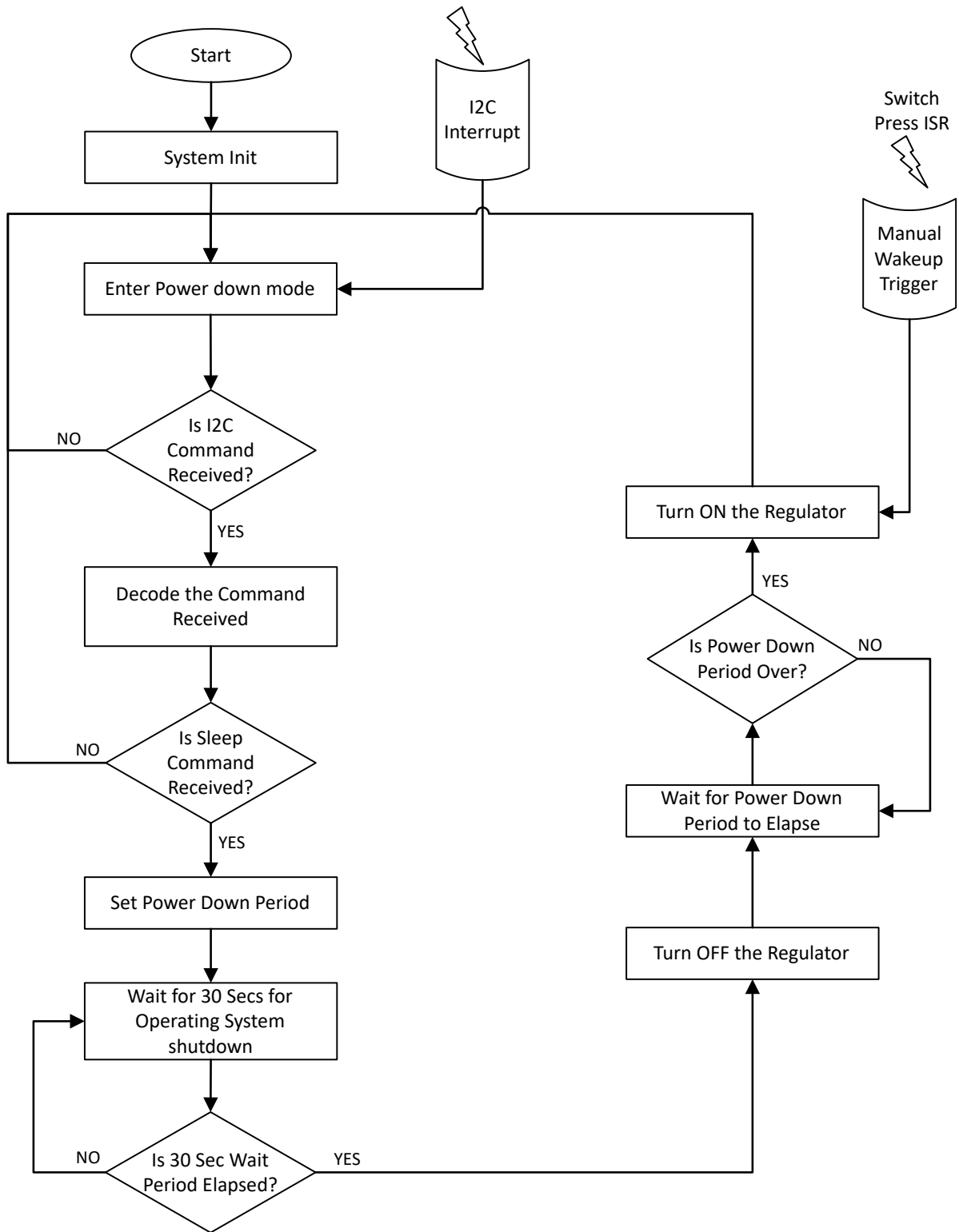


3.7 Supply Control Module Firmware Overview

The Supply Control Module application firmware starts with the initialization of the system and required peripherals of the PIC16F15244 microcontroller. After initialization, it enters Power-Down mode. The microcontroller remains in Power-Down mode until it receives an I²C command from the process computer. To an I²C interrupt, the microcontroller wakes up from Sleep and verify whether the received I²C command is valid.

On reception of a valid Sleep command, the control module waits for a period of 30 seconds using a timer peripheral before turning OFF the regulator. Once the 30 second wait period is over, the application firmware disables the I²C peripheral and turns OFF the LED (voltage regulator), then enters Low Power mode by entering sleep. This wait period can be configurable by the user per application requirement. The supply control device wakes up periodically from Sleep mode using the Watchdog Timer (WDT). After the total power-down duration is complete or if a valid switch press event is detected, the supply control module turns ON the LED. [Figure 3-5](#) shows the firmware flow of the application.

Figure 3-5. System Power Supply Control Firmware Flow Diagram



3.8 Microcontroller Configuration Details

Table 3-3 shows the PIC16F15244 microcontroller operating conditions and the peripherals configured on the supply control module for the system power supply control demo.

Table 3-3. Supply Control Module Microcontroller Configuration

Parameter	Value
Microcontroller	PIC16F15244
System Clock	HFINTOSC, 8 MHz
Operating Voltage	3.3V
MSSP Configuration	I ² C (in Client mode)
TMR0 Configuration	Overflow Interrupt Mode, 10 ms
Watchdog Configuration	Enabled, 8s
External Interrupt (EXT) Configuration.	Enabled, Pin RC2

3.9 Memory Consumption

Table 3-4 details the code and the data memory usage of the power supply control demo firmware developed with the PIC16F15244 microcontroller.

Table 3-4. Program and Data Memory Consumption

MPLAB Compiler Optimization	Program Memory in Bytes	Data Memory in Bytes
0	2411	133
1	2154	133
2	2084	133
3	1760	129
s	1760	129

3.10 Power Analysis

In the application, system power consumption is that of the process computer and the supply control module boards. When the process computer board is powered off, the total system power consumption is due to the supply control module board. So, in order to keep the average system power consumption to a minimum, it is important to configure the PIC16F15244 microcontroller on the supply control board in Sleep mode. As the sleep period of the microcontroller increases, the average power consumption of microcontroller decreases. Table 3.5 gives the current consumption data of the PIC16F15244 microcontroller with various sleep periods.

Note: Current consumption values for the PIC16F15244 microcontroller are captured using Microchip [Power Debugger](#) hardware and MPLAB [Data Visualizer](#).

Table 3-5. Current Consumption of PIC16F15244 Microcontroller

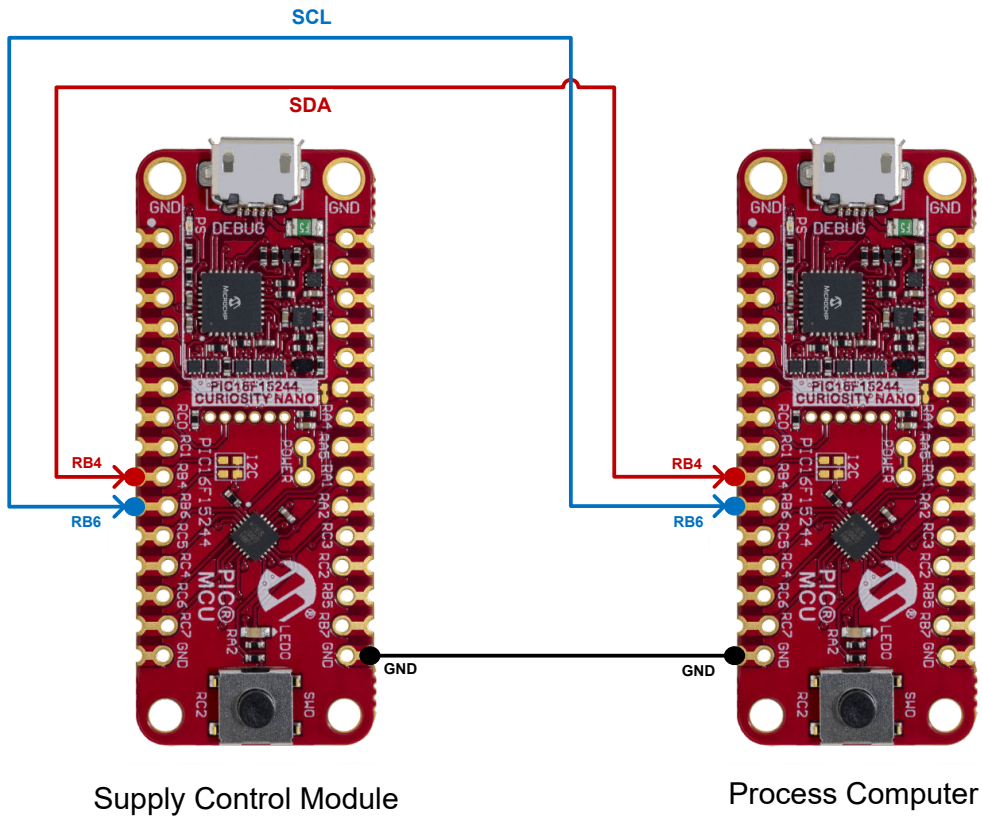
Active Current (μA)	Active Period (μs)	Sleep Current (μA)	Sleep Period (s)	Average Current (μA)
160	202	2	8	2
160	202	2	16	2
160	202	2	32	2

.....continued

Active Current (μA)	Active Period (μs)	Sleep Current (μA)	Sleep Period (s)	Average Current (μA)
160	202	2	64	2

3.11 Demonstration Setup

Figure 3-6. PIC16F15244 Curiosity Nano Evaluation Kit Hardware Setup



4. Real World Applications

In most of the power-critical real world applications designed using high-end 32-bit microcontrollers and microprocessors, using a separate integrated circuit for the effective system power supply control and management is a very common practice. Certain applications may require a simple power-supply control device, but with extended abilities such as dynamic configuration of system sleep duration and timely-control the system power supply through linear drop-out voltage regulator circuit. In applications such as these, using a PIC16F family microcontroller as the secondary microcontroller to control the system power supply meets the application requirements, and also keeps the solution cost-effective.

This section highlights a real-world application where a PIC16F family microcontroller can be used as secondary microcontroller in a system for power supply control.

A good example for a use case is a GPS tracking and driver-assistance device fitted in school transportation vehicles. The device is required to track vehicle movement for a fixed range of hours in the morning and evening, and goes into an inactive state for the rest of the time. The device draws power from the 12V battery of the vehicle's electrical system; the vehicle alternator keeps the battery charged while it is in running state. But there is a potential risk of the device draining the battery over extended inactive periods, such as weekends and holidays. To mitigate this problem, a PIC16F family microcontroller can be used as a secondary microcontroller on the tracking device to control the power supply of the device through a voltage regulator circuit. This allows the device to only power-up the process computer during the scheduled periods, thus avoiding running down the vehicle's battery.

There are numerous other applications where PIC16F family microcontrollers can be used as the secondary microcontroller for controlling the power supply of the system, such as:

- battery-powered outdoor weather stations
- automated vending machines
- automated ticketing systems
- digital signage
- home and building automation
- motor control

5. Conclusion

This application note presents developers with a brief overview of how an 8-bit microcontroller can be used to improve the power consumption of a process computer, such as an SBC.

The proof-of-concept application presented in this application note can be extended in various ways. For example, oscillator inaccuracies and start-up delays can be compensated for by monitoring the actual sleep time by the process computer itself. That way, the process computer can change the amount of time the system is expected to sleep. In addition, various real-time tasks can also be offloaded to the 8-bit PIC microcontroller.

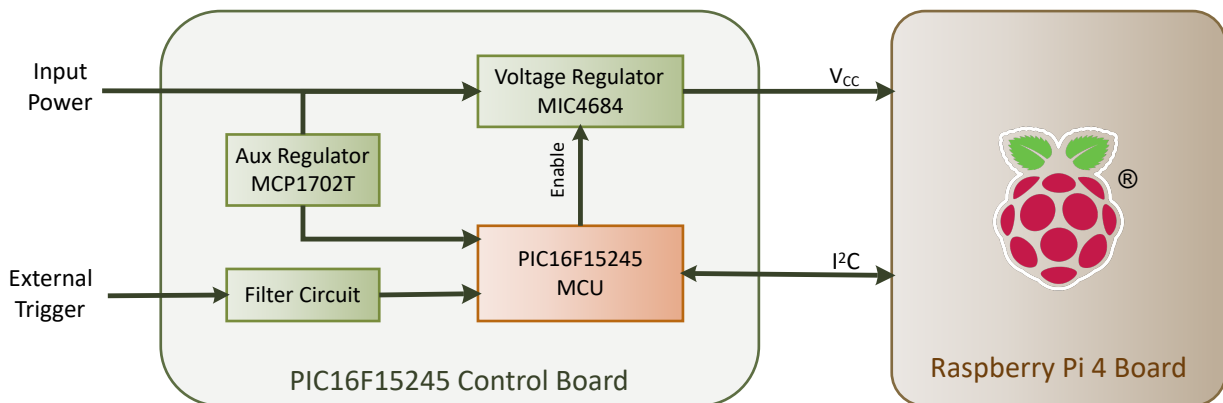
6. Appendix: System Power Supply Control for the Raspberry Pi® Application

This section demonstrates a use case of system power supply control for use with a Raspberry Pi-based reference application. The process computer functionality discussed here can also be implemented on other platforms, such as one of the Shenzhen Xunlong Orange Pi™ boards.

In the demonstration, the supply control module device will control the power consumption of the Raspberry Pi board when it needs to be put in Power-Down mode. A dedicated hardware board with a PIC16F15245 microcontroller and a MIC4684 switching regulator with enable control is used for power control of the Raspberry Pi board. The hardware also contains one MCP1702T low-dropout regulator to power the PIC16F15245 microcontroller. Figure 6-1 shows the block diagram of the hardware connections for the demonstration.

In case an immediate wake-up is needed for the Raspberry Pi board, the external trigger input is provided on the PIC16F15245 Control Board.

Figure 6-1. Hardware Connection for Raspberry Pi® Power Supply Control Demo



The application functionality is similar to the implementation based on the PIC16F15244 Curiosity Nano kit detailed in Section 3. [System Power Supply Control Emulation with the PIC16F15244 Microcontroller](#). The process computer implementation is switched to the Raspberry Pi board and supply control module implementation is moved to the dedicated hardware setup, a PIC16F15245 control board.

As described in section 3.1. [Application Overview](#), when it is time to shut down the Raspberry Pi board, it will send out the power-down command via an I²C communication interface to the PIC16F15245 microcontroller. The PIC16F15245 microcontroller then turns OFF the voltage regulator by controlling the Enable signal to the MIC4684. This will disconnect the Raspberry Pi board from power. After turning OFF the power, the PIC16F15245 microcontroller will go down into Low Power mode. This will save a significant amount of power for the entire system. The PIC16F15245 microcontroller will turn the power back ON again when the sleep duration has elapsed, or an external trigger is detected.

Note: “Raspberry Pi” and the Raspberry Pi logo are registered trademarks of the Raspberry Pi Foundation. “Orange Pi” is a trademark of the Shenzhen Zunlong Software CO., Ltd.

6.1 Application Firmware

The Firmware used for the PIC16F15245 microcontroller is same as the supply control module firmware described in Section 3.7. [Supply Control Module Firmware Overview](#). Refer to the corresponding section for more details.

Raspberry Pi Firmware

The Raspberry Pi 4 Board is programmed with an elementary firmware to send out the sleep command via the I²C interface on the switch press event. Raspberry Pi boards are programmed with the Python™ programming language in this application note.

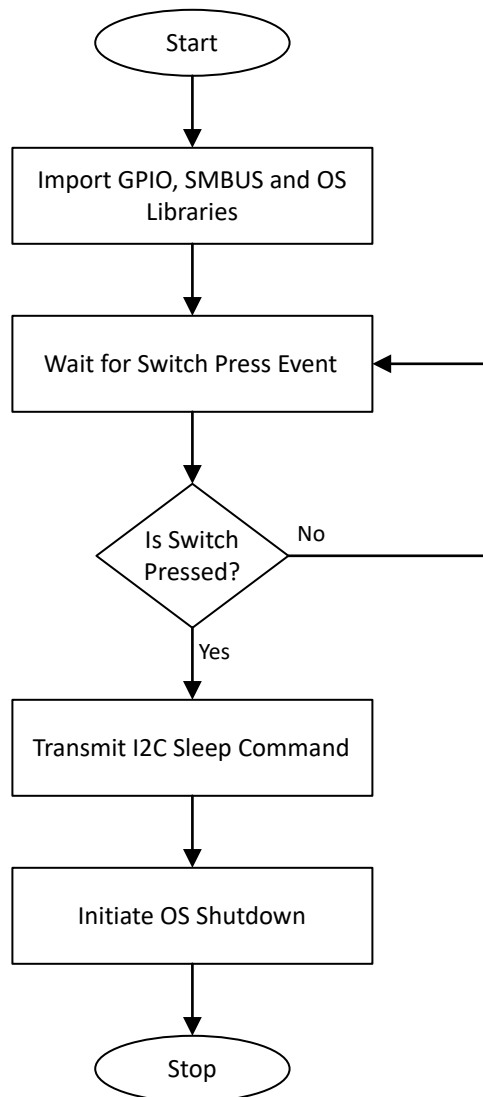


AN4121: PIC16F15245 Control Board Firmware

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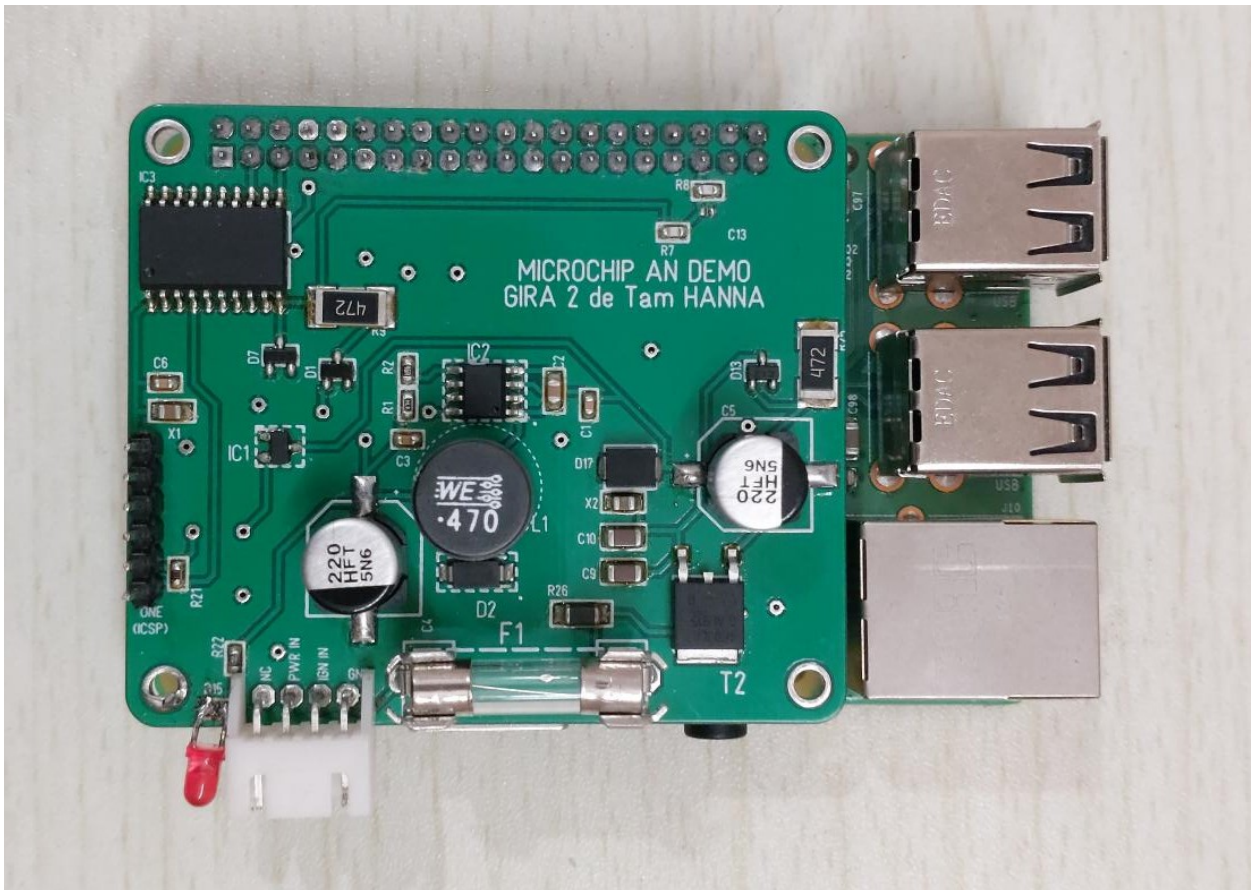
The figure below shows a simplified flow of the Raspberry Pi firmware.

Figure 6-2. Raspberry Pi® Firmware Flow Diagram



6.2 Demonstration Setup

Figure 6-3. Raspberry Pi® Hardware Setup



6.3 Power Analysis

While in Software Shutdown mode, the Raspberry Pi board consumes 1.6W of power, whereas the total system power consumption including the PIC16F15245 control board is 1.9W. Assuming a Raspberry Pi system needs to be active for 12 hours a day, the approximate power saved for one day is 19.2 Wh ($1.6W * 12h$). This power saved can further be improved if the PIC16F15245 microcontroller is put into Sleep mode. Table 6-1 gives the detailed power consumption of the application in Active and Sleep state with the Raspberry Pi board. In Active mode, the Raspberry Pi board consumes 2.5W, while the PIC16F15245 microcontroller on the Control board consumes 508 μ W.

Table 6-1. Power Consumption of the Total Application System

System State	Raspberry Pi Power Consumption (W) ⁽¹⁾	PIC16F15245 MCU Power Consumption (μ W) ⁽¹⁾	Total System Power Consumption (W) ^(1, 2, 3)
Active	2.5	508	2.9
Sleep	0	6.6	0.03

.....continued

System State	Raspberry Pi Power Consumption (W) ⁽¹⁾	PIC16F15245 MCU Power Consumption (μ W) ⁽¹⁾	Total System Power Consumption (W) ^(1, 2, 3)
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Notes:

1. Current consumption values for the PIC16F15245 microcontroller are captured using Microchip [Power Debugger](#) hardware and [MPLAB Data Visualizer](#) software.
2. The total system power consumption is the sum of the Raspberry Pi board power consumption and the PIC16F15245 Control board power consumption.
3. In the 'Total System Power Consumption' column, the excess power consumption is due to the additional hardware present on the PIC16F15245 Control board, such as the voltage regulator (MIC4684), the Aux Regulator (MCP1702T), and filter circuit.

6.4 PIC16F15245 Control Board Schematics

Figure 6-4. Regulator IC1 Schematic (Provides power to PIC microcontroller)

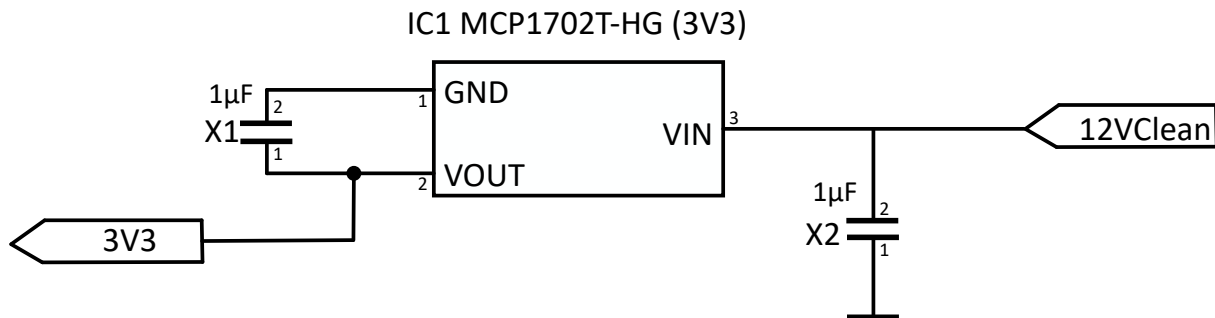


Figure 6-5. Regulator IC2 Schematic (Provides power to Raspberry Pi board)

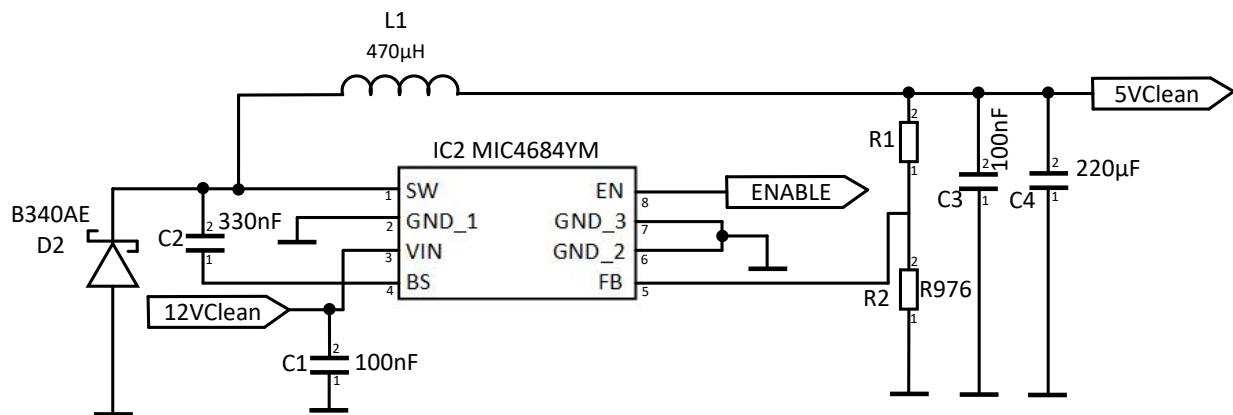
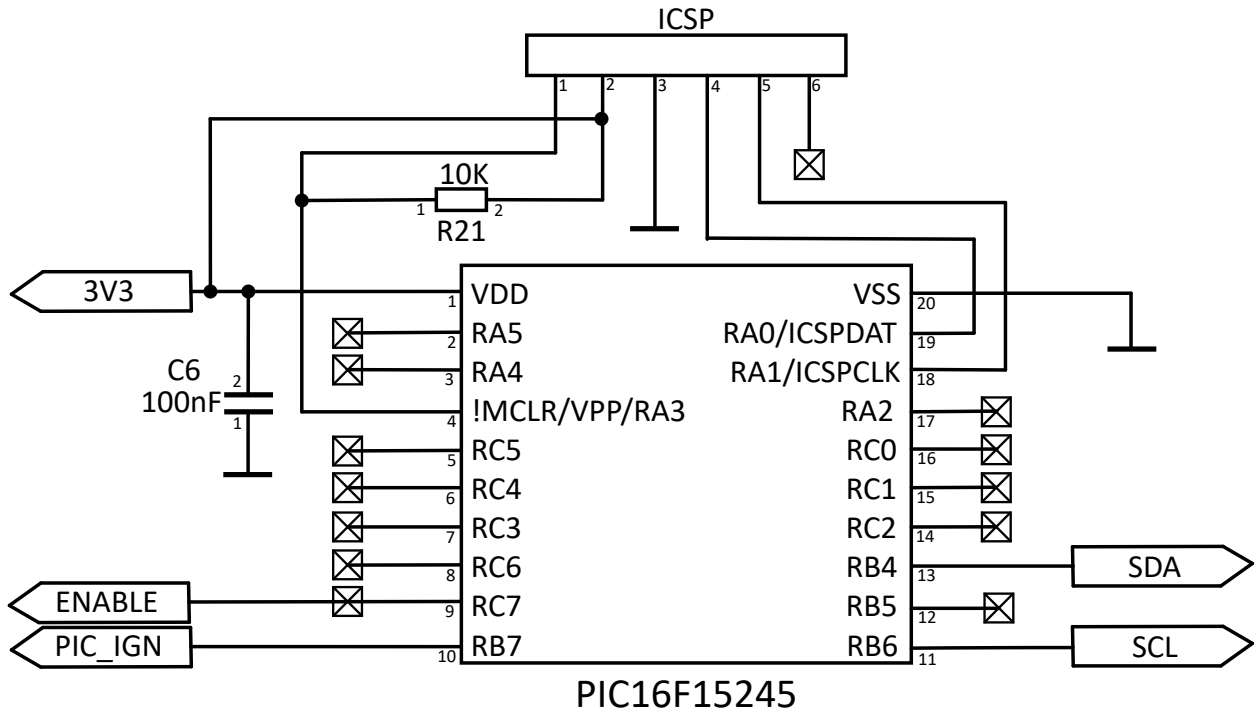


Figure 6-6. PIC16F15245 Schematic



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