INTRODUCTION

A patient monitor is a medical device used for continually monitoring a patient’s vital signs. The most common vital signs include heart rate, electrocardiogram data, blood pressure, blood oxygen saturation and body temperature. Patient monitors play a crucial role in virtually all aspects of medical care by continuously providing medical staff with information of the changes in general condition of a patient. Therefore, patient monitors require powerful microprocessors to perform high speed multitasking. Such tasks include controlling multiple biometric sensors, conditioning and measuring multiple vital signs, displaying waveforms and results simultaneously, handling user interface with a touch screen, storing medical data, and handling wired/wireless communications.

This application note describes an implementation of a patient monitor using Microchip’s SAMA5D2 Xplained Ultra development board with a touchscreen module and four Microchip medical demo boards. This demo provides a starting point for designing a complex, Linux® OS-based multitasking system utilizing a Microchip Smart ARM-based Microprocessor.

Microchip’s portable patient monitor demo system can measure a user’s heart rate, single-lead electrocardiogram (ECG), blood pressure, blood oxygen saturation (SPO2) and body temperature. Figure 1 shows the portable patient monitor demo main unit connected with a SPO2 probe, blood pressure cuff, ECG probes and infrared temperature sensor.

FIGURE 1: MICROCHIP PATIENT MONITOR DEMO
SYSTEM OVERVIEW

The patient monitor demo contains six subsystems. They are the SAMA5D2 Xplained Ultra Evaluation Kit (SAMA5D2C-XULT), a PDA TM7000 7in WVGA LCD display with maXTouch® Touch Module and four of Microchip’s medical demo boards: the Pulse Oximeter Demo Board, the Blood Pressure Monitor Demo Board, the ECG Demo Board and the Thermometer Demo Board. Figure 2 is the system diagram of the patient monitor demo showing all of the sub-systems.

FIGURE 2: PATIENT MONITOR DEMO SYSTEM DIAGRAM

The SAMA5D2C-XULT Evaluation Kit features a Cortex-A5® based MPU running Linux and is used for simultaneously processing data coming from multiple medical sensors, as well as controlling the LCD display and touch panel.

The TM7000 is a WVGA LCD and maXTouch® touchscreen module used to display measurement results and to provide a multi-touch user interface.

The pulse oximeter demo is used for measuring blood oxygen saturation and heart rate. The blood pressure meter demo is used for measuring blood pressure. The ECG demo is used for measuring electrocardiogram data. The thermometer demo is used for measuring skin temperature. Please refer to Appendix A for detailed information of each medical demo.

The four medical sub-demos were originally developed as individual medical demo systems. In this application four medical sub demo boards are integrated into the patient monitor system and measure a user’s vital signs independently. The four medical sub demo boards send the measurement data to the SAMA5D2C-XULT board via four independent UART channels. A GUI application based on Crank™ Software’s Storyboard™ Suite running on Linux processes the data received from each medical sub demo board and then displays the measurements on a 7in LCD with touchscreen.
HARDWARE OVERVIEW

Equipment List

1. SAMA5D2 Xplained Ultra Evaluation Kit (ATSAM5D2C-XULT Rev B)

The Microchip SAMA5D2XULT is a full-featured evaluation platform for Microchip’s SAMA5D2 series ARM-based embedded microprocessor units (eMPUs). It allows users to extensively evaluate, prototype and create application specific designs.

FIGURE 3: SAMA5D2 XPLAINED BOARD FUNCTION BLOCK DIAGRAM
2. TM7000 7in MaxTouch Touch Mobile

The 7in maxXTouch Touch Module made by PDA Inc. is a touchscreen module offering projected capacitance multi-touch functionality combined with a 7in, 800x480 resolution, 18-bit RGB LCD panel. The module is configured for development and evaluation with several of Microchip’s ARM-based EK solutions as well as development and integration with a custom host system.

The TM7000 Touch Module features a Microchip’s mXT768E maxXTouch Touch Controller supporting up to 10 touches on the touch display. The TM7000 is also equipped with Microchip’s AT42QT1070 QToucTH™ Button Sensor IC supporting 4 onboard touch buttons.

3. Pulse Oximeter Demo Board

A pulse oximeter is a non-invasive medical device that monitors the oxygen saturation (SPO2) of a patient’s blood and heart rate. Microchip’s pulse oximeter demo uses Microchip’s MCP4728 DAC, MCP6002 operational amplifier and dsPIC33FJ128GP802 16-bit Digital Signal Controller (DSC) to implement a transmissive type of pulse oximeter. There is no need for a complex/expensive analog front end (AFE) chip in this design. Among other tasks, the dsPIC33FJ128GP802 DSC implements a 513rd order, digital bandpass filter. This design demonstrates a robust implementation of a pulse oximeter.

4. Blood Pressure Meter Demo Board

A blood pressure meter (BPM) is a non-invasive medical device used to measure blood pressure. Microchip’s BPM demo uses Microchip’s MCP6N16 instrumentation amplifier and the PIC24FJ128GC010 16-bit microcontroller to implement a blood pressure meter based on the Measurement While Inflating (MWI) principle. This use of this technique coupled with Microchip’s eXtreme Low Power (XLP) parts makes this demo one of the lowest power consuming BPM designs available.

5. ECG Demo Board

Electrocardiography (ECG) is a non-invasive medical procedure to record the electrical activity of the heart over a period of time using the differential voltage collected from electrodes placed on the skin. Microchip’s
ECG demo uses Microchip’s ATSAML22N18A 32-bit ARM Cortex M0+ microcontroller with an ECG sensor to implement a single-lead (2 to 3 electrode contacts) type of electrocardiogram machine.

6. Thermometer Demo Board
Microchip’s thermometer demo uses a PIC16F1519 8-bit microcontroller and an infrared temperature sensor to measure the skin temperature.

SOFTWARE
The ATSAMA5D27C-CU MPU used on SAMA5D2 Xplained evaluation board runs the Linux® OS. Microchip hosts the AT91 community website (www.at91.com/linux4sam/) with resources dedicated to developing software for various evaluation boards with Smart ARM-based Microprocessors (aka SAM) for Linux. The Linux Kernel includes basic support for maxTouch touch devices.

The patient monitor demo operating system is based on the Linux4SAM 5.5 TM7000 demo release for the SAMA5D2 Xplained board. Changes were made to the Linux device tree to add UART support for the communication with medical boards, and the root file system has been updated to run the Patient Monitor demo at boot.

Crank Software’s Storyboard Suite
The patient monitor demo running on the SAMA5D2 Xplained board was created using Storyboard Suite, an embedded UI development framework developed by Crank Software.

The SAMA5D2 Xplained board boots a Yocto Linux image supporting a wide array of devices, such as single and multitouch input displays and external peripheral integration. Storyboard supports the Linux operating system, which allows designers to create a rich user interface on the SAMA5D2 Xplained board. The patient monitor demo consists of a Storyboard UI which can display real-time patient information from connected vitals sensor boards.

The data input and output for the sensor boards are aggregated through a C application that communicates to the UI through Storyboard’s I/O interface called Storyboard IO. Storyboard IO decouples the UI from backend systems by defining a series of events and structured data payloads. Defining event and data payloads in Storyboard allows the UI to be developed in parallel to the backend. Events and data can be simulated and injected into a running UI without needing to deploy it to the embedded hardware. This greatly reduced the development, integration, and testing cycles required to complete the demo. When the backend was ready, the UI was able to be dropped onto the embedded hardware for testing and integration.

UART COMMUNICATION
Each medical demo board sends measurement data to the SAMA5D2 Xplained board via UART port in a specific serial data format which contains a header and followed by user data. Using the pulse oximeter function as an example, the pulse oximeter demo outputs an ASCII character stream in a format as listed below:

```
00015;00743;00099;00055;
00015;00743;00099;00055;
00015;00743;00099;00055;
00015;00743;00099;00055;
00015;00744;00099;00055;
...}
```

Each data field in each packet/line is separated by a semicolon. Take the first packet/line as an example:

```
00015 is the header.
00743 is the pulsation waveform data.
00099 is the blood oxygen level (SPO2 =99%).
00055 is the heart rate (55 bpm (beat per minutes)).
```

The patient monitor demo software can also control the pulse oximeter board via UART connection. For example, when user presses the pulse oximeter reset button on the touch screen, a reset command (0x72) is issued to the pulse oximeter board via UART port to soft-reset the pulse oximeter demo.
DEMO OPERATION

First, insert the medical demo probes that come with the patient monitor demo into corresponding connectors located on either side of the patient monitor demo (see Figure 5 and Figure 6). Then power on the patient monitor demo using the 5V 2A DC power supply included with the patient monitor demo.

FIGURE 5: SPO2 PROBE AND BPM CUFF CONNECTORS

FIGURE 6: ECG PROBE AND TEMPERATURE PROBE CONNECTORS
The patient monitor demo will display a main menu when it is booted up. Four windows in the center of the main menu display the user’s real-time vital signs – ECG, blood pressure, SPO2, heart rate and skin temperature. The user may put multiple probes on to take measurements simultaneously. Figure 7 shows the main menu.

**FIGURE 7:** PATIENT MONITOR DEMO MAIN MENU DISPLAYING ECG, SPO2, BPM AND TEMPERATURE

The user may press each vital sign function touch button, located in the windows in the main menu, to get more information during a measurement (see Figure 8, Figure 9 and Figure 10).
FIGURE 8: ECG FUNCTION SHOWING DEMO WAVEFORM

FIGURE 9: SPO2 FUNCTION SHOWING OXYGEN SATURATION MEASUREMENT AND PULSATION WAVEFORM
FIGURE 10: BPM FUNCTION SHOWING BLOOD PRESSURE MEASUREMENT AND PULSATION WAVEFORM
APPENDIX A: REFERENCES

Microchip Patient Monitor Demo Landing Page:
http://www.microchip.com/design-centers/medical/applications/patient-monitor

Microchip Pulse Oximeter Demo Landing Page:
http://www.microchip.com/promo/pulse-oximeter-demonstration

Microchip, App Note AN1525, Pulse Oximeter Design Using Microchip's Analog Devices and dsPIC® Digital Signal Controllers (DSCs)

Microchip Blood Pressure Meter Demo Landing Page:
http://www.microchip.com/promo/low-power-blood-pressure-meter-demonstration

Microchip, App Note AN1556, Blood Pressure Meter Design Using Microchip's Analog Devices and PIC24F Microcontrollers

Microchip ECG Demo Landing Page:
http://www.microchip.com/promo/connected-wearable-electrocardiogram-(ecg)-demo

Microchip, Wearable Electrocardiogram Reference Design User’s Guide, DS70005345A

Microchip Thermometer Demo Landing Page:
http://www.microchip.com/promo/connected-thermometer-demo-page

Microchip SAMA5D2 Xplained Ultra Evaluation Board ATSAMA5D2C-XULT:
http://www.microchip.com/developmenttools/productdetails/partno/atsama5d2c-xult

Linux4SAM community website:
http://www.at91.com/linux4sam/bin/view/Linux4SAM
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