June, 2010

Intelligent Hospitals and Telemonitoring Solutions

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The Intelligent Hospitals demo is a data-acquisition system that can help assess the health of a person in a determined time.

It enables telemedicine because it can be used at a patient’s home and transmit data to a remote healthcare facility.

It acquires the following medical data:

- Blood Pressure
- Heart Rate
- EKG
- Weight
- Body Mass Index
- Height
- Thermometer
- Pulse Oximetry
- Spirometry
- Blood Glucose
System Parts

► The system can be used as a stand-alone/telemonitoring system or basic first aid supplier

► Stand-alone
  • Weighing scale, thermometer, blood pressure, blood glucose, 1-lead EKG, lung function through spirometry, pulse oximetry, height

► Home monitoring system
  • The previous devices can be set up in one demo, allowing the doctor to assess what data is needed from the patient at the patient’s home without losing time at the hospital or doctor’s office

► First aid supplier
  • The Medical Kiosk is a low-cost solution that lets patients send their data to a hospital and through defibrillators and D&T devices, helping prevent acute complications from disease
When a doctor logs into the system, they see all of the patient’s data in real time.

Real Time Data

- Patient: Name
- ID: Hospital ID Number

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TEOR</th>
<th>MEJOR</th>
<th>%TEOR</th>
</tr>
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<tr>
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<td>5.02</td>
<td>99</td>
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<tr>
<td>FVC</td>
<td>5.05</td>
<td>5.02</td>
<td>99</td>
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<tr>
<td>FEV1</td>
<td>4.21</td>
<td>4.08</td>
<td>97</td>
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<tr>
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<td>81.4</td>
<td>96</td>
</tr>
<tr>
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<td>84.4</td>
<td>81.4</td>
<td>96</td>
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<tr>
<td>FEV1/FVC</td>
<td>81.9</td>
<td>81.9</td>
<td>100</td>
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<td>PEF</td>
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<td>FEF25</td>
<td>10.02</td>
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<td>6.32</td>
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<td>FEF2575</td>
<td>5.12</td>
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<td>75</td>
</tr>
<tr>
<td>FEF60</td>
<td>4.99</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hospital Name
20/11/2009
10:28

64 bpm
98% SpO2

Touch to begin measurement
Insert strip and place blood sample

Intelligent Hospitals graphic user interface with touch screen.
Patient Log In

► When a patient logs in, he or she sees the following step-by-step video/audio instructions on how to use the medical devices

- Supports three languages: English, Spanish and Japanese
The patient sees a video that shows step-by-step how to acquire vital signs and perform medical tests.

The communication system of the kiosk sends all the patient’s data to a remote database and informs healthcare professionals if assistance is needed.

Through software in the second pass we set up VoIP and video transmission to allow a remote healthcare professional to assist and perform remote diagnosis.
About Preventive Medicine

By performing these tests and acquiring vital signs, the system helps avoid/prevent acute complications of chronic degenerative diseases, and gives early and prompt diagnosis.

- Cardiac disease
- High blood pressure
- Diabetes mellitus / gestational diabetes
- Chronic obstructive pulmonary disease (COPD)

• Health
• Quality of Life
• Economy
The system is in sync with the global efforts of health institutions to control the top causes of death and morbidity.
Freescale Products

MCUs
S08LL/S08LH/S08JM
i.MX35
Flexis S08MM

Wireless
ZigBee® Healthcare profile

Software enablement
Touchscreen
USB Personal Healthcare Profile
IEEE® 11073 Medical SW suite

Sensors
Single input and differential pressure sensors

Intelligent Hospitals Demo

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Intelligent Hospitals: Reference Design

- Spirometer: MPXV7025
- Medical Board: TWR-MM
- Medical Kiosk: i.MX 35/51
- Temperature, Weight & Height: MPC17C724
- Communications Board: S08JM & MC13213
- Electrocardiograph: MC56F8006
- LCD Board: S08LL
- Pulse Oximeter: MPC17C724
- Blood Glucose Meter: MC56F8006
- Blood Pressure Monitor: MPX3V5050
- Spirometer: MPXV7025
- Blood Glucose Meter: MC56F8006
- Blood Pressure Monitor: MPX3V5050
- Electrocardiograph: MC56F8006
- Communications Board: S08JM & MC13213
- Medical Board: TWR-MM
- Medical Kiosk: i.MX 35/51
Use Cases

► Low-end solutions with S08LL, S08LH

► System integration through S08MM

► Mid-range solutions with S08JM

► High-end solutions with i.MX, S08MM
Analog Front Ends

* For S08MM Tower System
The LCD control board will have:

- Rechargeable Li-On battery
- Battery charger circuit
- LCD (Apgar)
- LL16
- Three electrodes that will work as buttons
- Three LEDs
- One AFE connector for glucometer, pulse oximeter or blood pressure monitor
MC9S08LH64/36: High Resolution ADC

- **Design Considerations**
  - Ultra-low power
  - S08 core
  - 1.8V – 3.6V

- **Availability**
  - LH64 Beta samples: January 2010
  - LH64 Qualification: Jun 2010 (MC)

- **LCD Driver**
  - Up to 288 segment LCD drive (8x mode)
  - BP/FP reassignment
  - Blink operation in low-power modes
  - Drive 3V and 5V LCD glass

- **Features**
  - 2xSCIs, IIC, SPI, KBI, TOD, ACMP
  - 2x2ch 16-bit TPM
  - 10-ch 16-bit ADC, 2 dedicated differentials
  - VREF1.2 (1.2v – 40PPM/°C)
  - EEPROM emulation
  - 80LQFP/64LQFP package
  - Up to 39 GPIO

- **Memory**
  - Dual bank 32K flash
  - 4K RAM

- **Internal Clock Source (ICS)**
  - FLL
  - On chip oscillator
  - External crystal support
    - (32 Khz, 1-16 Mhz)
  - 2% accuracy over full operating range

- **Development Tools**
  - On chip BDM
The Tower System

**Functional Elevator:**
- Common serial and expansion bus signals
- Two 2x80 connectors on backside for easy signal access and side-mounting board (e.g. LCD module)
- Power regulation circuitry
- Standardized signal assignments

**Board Connectors:**
- Four card-edge connectors
- Uses PCI Express connectors (x16, 90mm/3.5” long, 164 pins)

**Peripheral Module (Prototype)**

**MCU/MPU Module:**
- Tower controller board
- Works stand-alone or in Tower system
- Features new Open Source BDM (OSBDM) for easy programming and debugging via miniB USB cable
- **Size:** The Tower is approx. 3.5” H x 3.5” W x 3.5” D when fully assembled

**Dummy Elevator:**
- Future expansion for more serial interfaces and more complex MPU interfaces (e.g. RGB LCD, audio, enhanced Timer, etc.)
- “Dummy” shown with only GND connectivity. Used for structural integrity
# Current MCU Solutions for Home Portable Medical

<table>
<thead>
<tr>
<th>Feature</th>
<th>9S08LL16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Key Feature</strong></td>
<td>192 segment LCD ctrl</td>
</tr>
<tr>
<td>Core</td>
<td>S08 (8bit)</td>
</tr>
<tr>
<td></td>
<td>20 MHz core</td>
</tr>
<tr>
<td></td>
<td>10 MHz bus</td>
</tr>
<tr>
<td>Flash / SRAM</td>
<td>16K (dual 8K Flash arrays)</td>
</tr>
<tr>
<td></td>
<td>2K RAM</td>
</tr>
<tr>
<td>A/D</td>
<td>12bit</td>
</tr>
<tr>
<td>Timers</td>
<td>2x 2ch 16-bit</td>
</tr>
<tr>
<td>Communications</td>
<td>SCI, SPI, IIC</td>
</tr>
<tr>
<td>Package</td>
<td>65 LQFP</td>
</tr>
</tbody>
</table>
Communications Board

► Power jack (5V-12V DC) provides power to all AFEs and the voltage to recharge the LCD board battery
► JM60 (64-pin LQFP) with USB connector
► ZigBee transceiver (MC13224)
► Bluetooth transceiver (LMX9838)
► Expansion connector
► AFE connector for:
  • Glucose meter
  • Blood pressure monitor
  • ECG
  • Thermometer, weight scale and height scale
  • Spirometer
  • Pulse oximeter
  • Power management circuit to provide 5V even when the battery is 3.3V
Introducing the Flexis USB Family: S08JM60 and MCF51JM128

- 48 MHz S08 or ColdFire V1 core
- 24 MHz bus frequency
- 2.7—5.0V operating range
- Memory
  - S08
    - Up to 4 KBytes SRAM; up to 60KB flash
  - ColdFire V1
    - Up to 16 KBytes SRAM; up to 128 KB flash
- Features
  - 2x SCI, I²C, 2x SPI
  - 8 channel KBI
  - 16-bit timers: 1 x 2-ch, 1 x 6-ch
  - 12-bit 12 channel A-to-D converter
  - Analog comparator
  - Up to 51 general purpose I/O
  - Multiple Purpose Clock Generation
    - PLL
    - On-chip oscillator
    - External crystal support
  - Integrated CAN module (ColdFire V1 only)
  - Cryptographic acceleration unit (ColdFire V1 only)
- Complete USB Solution
  - Integrated USB device (S08) or USB on-the-go (ColdFire V1)
  - Complimentary USB software stack
  - CodeWarrior for Microcontrollers
  - Processor Expert

S08JM60 Packages
- 64LQFP, 64QFP 48QFN, 44LQFP

ColdFire JM128 Packages
- 80LQFP, 64LQFP, 64QFP, 44LQFP

Temperature Range
- -40°C to 85°C
Features / Benefits
- Timers – 1 x 2-ch, 1 x 6-ch
- Upgraded SPI configurable for 8-bit or 16-bit data length
- Analog comparator
- 8-ch keyboard interrupt (KBI)
- 8-bit 12-ch ADC
- LVI
- 39 (muxed) GPIOs for 48-pin package
- Integrated USB 2.0 FS PHY and SIE
- Multi-purpose clock generator (MCG)
  - PLL
  - On-chip oscillator
  - External crystal support
- On-chip ICE and BDM

Supply Voltage / Performance
- 2.7 – 5.0 V operation
- -40° to 85°C operation

Core
- 48 MHz HCS08 core
- 24 MHz bus frequency

Memory
- 16K Flash, 1K RAM, 128B USB RAM

Communications
- SCI, SPI, IIC w/ broadcast mode feature

Packages
- 32 LQFP, 44 LQFP, 48 QFN

Pricing
- $1.99* MSRP at 10K units
  *Varies by package
ZigBee Health Care provides a global standard for interoperable wireless devices enabling secure and reliable monitoring and management of noncritical, low-acuity healthcare services targeted at chronic disease management, obesity and ageing. ZigBee Health Care is designed for use in homes, fitness centers, retirement communities, nursing homes and a variety of medical care facilities.
MM Tower Boards

TWR- ELEV

TWR-MM

TWR-SER

TWR-AFE
Scalability and Use

► Tower for Flexis MM
  • Integrated analog
  • Measurement engine
  • Low power
  • Connectivity
  • Multiple-device standalone (patient monitoring system)
### Medical Connector

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
<th>Signal</th>
<th>GND</th>
<th>2</th>
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<tbody>
<tr>
<td>1</td>
<td>5v</td>
<td>GND</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>PWM1/GPIO1/SDA</td>
<td>PWM/GPIO2/IRQ or KBI/SCL</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>ADC1</td>
<td>ADC2</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>MM Comparator</td>
<td>MM DAC / Vref</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>MM Opamp A Out</td>
<td>MM Opamp D Out</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>MM Opamp A -</td>
<td>MM Opamp D -</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>MM Opamp A +</td>
<td>MM Opamp D +</td>
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<td>15</td>
<td>MM Opamp B +</td>
<td>MM Opamp C +</td>
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<td>16</td>
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<tr>
<td>17</td>
<td>MM Opamp B -</td>
<td>MM Opamp C -</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>19</td>
<td>MM Opamp B Out</td>
<td>MM Opamp C Out</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

*To be multiplexed by hardware by a jumper.*

**Table 1:** 2x10 pin header connector. AFE signals pinout
Core and Memory
- 8-bit 9S08 core running up to 50 MHz
- Supports up to 128 KB flash and 12 KB SRAM

Measurement Engine
- 2 x trans-impedance amplifiers
- 2 x general purpose amplifiers
  - Configurable low pass filters, unity gain buffer, PGA
- 16-bit ADC (Up to 14.5 bits ENOB)
- 12-bit DAC (16 x FIFO word Buffers)
- Voltage reference
  - 1.17V 40PPM/°C + 8 bits trimmable register
- Programmable delay block
- Timing and synchronizing measurement events

Connectivity Support
- USB 2.0 / On the Go available on 32 bit
- 2x SCI
- 2x SPI
- IIC

Low Power
- 9S08MM - 480 nA STOP2
- Low power time of date (TOD)
Op Amp:
- Trans impedance amp functionality
- Low pass filter

16-bit SAR ADC
- Differential input mode
- 14.5-bit accuracy
- Offset and gain control
- Hardware average
- Window compare mode

IRTC:
- Separate power rails
- Power removal detection

Motor Control
- Very low power:
  - Stop Idd: 0.350uA
  - Short Stop recovery time: 6uS

BIOSENSOR
- Photodetector or Coulometer

Test Strip

Monochrome or segment LCD

3x Op Amp
DAC
KBI
2x SPI
16-bit SAR ADC
VREF
PDB
2x SCI
IRTC
PRACMP
COP
IIC
128K FLASH
12K RAM
USB Full Speed
4x TPM
4x TPM
MCG
LVI
40 GPIO
S08 Core
48Mhz
### Core and Memory
- 32-bit ColdFire V1 core running up to **50 MHz**
- Supports up to 256 KB flash and 32 KB SRAM

### Measurement Engine
- 2 x trans-impedance amplifiers
- 2 x general purpose amplifiers
  - Configurable, low pass filters, unity gain buffer, PGA
- 16 bit ADC (Up to **14.5 bits ENOB**)
- 12 bit DAC (16 x FIFO word buffers)
- Voltage reference
  - 1.17V 40PPM/°C + 8 bits trimmable register
  - Programmable delay block
  - Timing and synchronizing measurement events

### Connectivity Support
- USB 2.0 / On the Go available on 32 bit
- 2x SCI
- 2x SPI
- IIC

### Low Power
- **MCF51MM256 - 650 nA STOP2**
- Low power time of date (TOD)

### Graphics and external memory expansion support
- MiniBus – External Bus Interface

---

**MCF51MM256**

**Measurement Engine**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x OPAMP</td>
<td></td>
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<tr>
<td>2x TRIAMP</td>
<td></td>
</tr>
<tr>
<td>16 bit SAR ADC</td>
<td></td>
</tr>
<tr>
<td>12 bit DAC</td>
<td></td>
</tr>
<tr>
<td>LVI</td>
<td></td>
</tr>
<tr>
<td>IIC</td>
<td></td>
</tr>
<tr>
<td>PDB</td>
<td></td>
</tr>
<tr>
<td>PRACMP</td>
<td></td>
</tr>
<tr>
<td>CMT</td>
<td></td>
</tr>
<tr>
<td>PWM</td>
<td></td>
</tr>
<tr>
<td>2x 4ch TPM</td>
<td></td>
</tr>
<tr>
<td>2 x SPI</td>
<td></td>
</tr>
<tr>
<td>MCG</td>
<td></td>
</tr>
<tr>
<td>KBI</td>
<td></td>
</tr>
<tr>
<td>2 x SCI</td>
<td></td>
</tr>
<tr>
<td>256 KBytes Flash</td>
<td></td>
</tr>
<tr>
<td>Bootloader</td>
<td>USB ROM</td>
</tr>
<tr>
<td>32 Kbytes SRAM</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>32-bit V1 ColdFire</strong></td>
</tr>
<tr>
<td></td>
<td><strong>50 MHz Core with MAC</strong></td>
</tr>
</tbody>
</table>

**Connectivity Support**

- **USB Device/Host/OTG**
- **MiniBus External Bus**
- **IIC**

**Low Power**

- **MCF51MM256 - 650 nA STOP2**
- Low power time of date (TOD)
Op Amp:
- Trans impedance amp functionality
- Low pass filter

BIOSENSOR
- Photodetector OR Coulometer

16 bit SAR ADC
- Differential input mode
- 14.5 bit accuracy
- Offset and gain control
- Hardware average
- Window compare mode

16x Op Amp

3x Op Amp

DAC

KBI

2x SPI

VREF

PDB

2x SCI

16 bit SAR ADC

IRTC:
- Separate power rails
- Power removal detection

Motor Control

- EMAC
- Up to 25 MHz bus
- Very low power:
  - Stop Idd: 0.550uA
  - Short Stop recovery time: 6uS

3x TPM

256K FLASH

24K RAM

USB Full Speed

V1 Core 60Mhz

Mini Bus

4x TPM

MCU

CAN

18 GPIO

- Memory expansion: up to 4 MBytes
- 1 MB without glue logic
- Can drive memory interface LCD

Bus interface LCD

Test Strip

From 1.5 to 15-Inch Displays
Serial interface LCD
Measurement Engine IP Specifics

- Measurement Engine Contains
  - 16b analog-digital converter
    - SAR type; up to 14.5b accuracy
  - 12b digital-analog converter
    - 1μs settling time
  - Programmable delay block
    - Synchronizes ADC and DAC operations
  - 1.2V trimmable voltage reference
    - 33 ppm/C variation
  - General purpose operational amplifier
    - Customizable function – filter, PGA
  - Trans-impedance amplifier
    - Low input bias current operation
  - Analog comparator with prog. reference
    - Low power wakeup on analog threshold

- Measurement Engine Functions
  - Static and dynamic biasing
  - Signal conditioning
  - High accuracy measurement

[Diagram showing the connections between VREF, 2-TRIAMP, 2-OPAMP, PDB, ADC, and DAC.]
Measurement Engine

- Dynamic and Static Biasing
  - Low temperature drift output
  - Trimmed output
  - Selectable voltage reference
  - Current drivers

- Signal Conditioning
  - Trans-impedance amplifier
  - Low pass filter
  - Unity gain buffer
  - Gain amplifier

VREF to external components
External Voltage reference
External Voltage Input

2-TRIAMP
(500pA bias current)
2-OPAMP
(2nA bias current)
(Internal resistor ladder)

ADC
16 bit w/8 register and result registers

DAC
12 bit w/ 16 word FIFO buffer

Programmable Delay Block PDB
(16 bit Counter)

(9 – 16 bit registers)
These processors are ideal for applications that require advanced user interfaces, sophisticated video processing, 2D and 3D graphics, multiple connectivity options and a high level of system integration.
Home Portable Using i.MX
Video and Patient Monitoring Screens
Benefits

► The system will allow medical professionals to remotely locate and identify patients who need primary assistance for an emergency, cutting government costs for one of the largest expenses in health services.

► By providing easy and low-cost medical care and performing preventive medicine, it will avoid acute complications of the chronic degenerative diseases which account for the largest expenses in the elderly population.

► Telemonitoring solutions will allow medical control from home, which is the gold standard for modern disease control.
Other Considerations

► When used as a hospital admission machine, the system reduces the time in which the patient is first validated by a healthcare provider.

► A first trial with 67 people using the Kiosk in Freescale’s facilities in Mexico showed that the average time to perform all the medical tests by a physician took 7.1 minutes per patient — standard is around 30 minutes.

► Automatically refreshes medical databases with patients’ new data.

► Allows remote health assistance and control, focusing on a broader range of pathologies (cardiovascular, chronic-degenerative and pulmonary)
Please visit our booth at the Demo Lab