How to Create a Heart Rate Monitor and One-Lead EKG

Low-cost, battery-operated system

Jose Fernández Villaseñor, M.D.
Medical Microcontroller Product Marketing
Worldwide Morbidity 2007

Worldwide Incidence 2007

<table>
<thead>
<tr>
<th>Disease</th>
<th>Incidence (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>600</td>
</tr>
<tr>
<td>Heart attack</td>
<td>32</td>
</tr>
<tr>
<td>Stroke</td>
<td>15</td>
</tr>
<tr>
<td>Ischemic Heart Disease</td>
<td>171</td>
</tr>
<tr>
<td>Colorectal Cancer</td>
<td>0.5</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>0.42</td>
</tr>
<tr>
<td>Breast Cancer</td>
<td>1.23</td>
</tr>
<tr>
<td>Colorectal Cancer</td>
<td>0.59</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>1.03</td>
</tr>
<tr>
<td>Prostate Cancer</td>
<td>0.73</td>
</tr>
<tr>
<td>Diabetes</td>
<td>171</td>
</tr>
</tbody>
</table>

Heart Rate Monitoring Technologies

Early 20th Century

Saline-filled bucket electrodes

Today
Heart Physiology: Cardiac Conduction System

- Right atrium
- Atrioventricular node
- Sinoatrial node (pacemaker)
- Atrioventricular bundle
- Purkinje fibers
- Right Ventricle
- Purkinje fibers
- Bundle branches
Heart Physiology: Origin of the Electrocardiogram

- SA Node
- Atrial Muscle
- AV Node
- Common Bundle
- Bundle Branches
- Purkinje Fibers
- Ventricular Muscle

Action Potentials

Seconds

0.2 0.4 0.6

P QRS T U
Heart Physiology: Electrocardiogram (ECG)

- Composite of all action potentials of nodal and myocardial cells detected, amplified and recorded by electrodes on arms, legs and chest.
Heart Physiology: Electrical Activity of Myocardium

1) Atria begin to depolarize

2) Atria depolarize

3) Ventricles begin to depolarize at apex; atria repolarize

4) Ventricles depolarize

5) Ventricles begin to repolarize at apex

6) Ventricles repolarize
Acquiring Heart Signals: Typical Instrumentation System

- **Sensor**: Takes the signal from the body
- **Amplifier**: "Conditions" the signal from the sensor
- **A/D Converter**: Changes the signal into a digital format
- **Controller**: Processes, displays and records the signal
Acquiring Heart Signals: Electrode-Skin Interface

Offset sources:
- Electrode
- Skin
- Breathing

Sweat glands and ducts
Acquiring Heart Signals: OPAMP array for an INA

CMRR = \(10 \log (1 + \frac{2R2}{R1})\)

Gain = \(\frac{R4}{R3(1 + \frac{R2}{R1})}\)
Acquiring Heart Signals: Common Mode Rejection Ratio (CMRR)

- The CMRR defines the ability of the amplifier to reject signals that are common to both inputs.
- This is important for 60Hz rejection.
- CMRR is a function of gain.
- CMRR is frequency-dependent.
- Highest CMRR between 0-100 Hz.
Acquiring Heart Signals: Connections to INA

$m$ is signal from muscle, $n$ is noise

Differential Amplification

\[(m_1+n)-(m_2+n) = m_1-m_2\]
Bipolar limb leads:
I, II, III
Acquiring Heart Signals: Chest Leads

► Additional set of six leads, placed on the chest
Low-cost Heart Rate Monitor: Importance of Measuring Heart Rate

![Heart Rate Zones Graph](Image)

- **Warm-Up/Cool-Down Zone**
- **Fat Burning Zone**
- **Target Heart Rate Zone**
- **Anaerobic/High Intensity Zone**

Heart Rate - Beats per Minute

- **80**
- **100**
- **120**
- **140**
- **160**
- **180**
- **200**

% of Max. Heart Rate

- 85% - 100%
- 65% - 85%
- 50% - 65%
- 50% or Less

Age

- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65+

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners. © Freescale Semiconductor, Inc. 2009.
Low-cost Heart Rate Monitor: Market Solutions
Low-cost Heart Rate Monitor

The diagram shows a block diagram of a low-cost heart rate monitor. The system includes a MC9RS08KA2 MCU (8-pin SOIC) as the central processing unit. The MCU is connected to various components including BDM Connector, SCI Connector, PWR (2), BDM/SCI (2), GPIO (1), Alarm LED, Heart Beat Buzz & LED, ACMP (1), Electrode - and Electrode +. The system also includes a Reference and an Instrumentation Amplifier.
1 to 12-Lead ECG Solution

ECG USB

Heart Rate

MC9S08JM60CFGE
- SCI_1
- SPI
- USB
- ADC
- SCI_2

Zero Drift Amp

Bluetooth Tx/Rx

MC56F8013VFAE
- SPI
- MAC Process
- ADC

JTAGECG USB

R Foot
AvF
AvR
AvL
D[1:6]
The Flexis™ USB Family
S08JM60 and MCF51JM128

- 48MHz S08 or ColdFire® V1 core
- 24MHz bus frequency
- 2.7 – 5.0V operating range

**Memory**

- **S08**
  - Up to 4KBytes SRAM; up to 60KB flash
- **ColdFire V1**
  - Up to 16KBytes SRAM; up to 128KB 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
Complete Solution
Complete Solution
Low-cost Heart Rate Monitor
Lab0. Get familiar with the HRM

Connect the chest electrodes

Like this!
Low-cost Heart Rate Monitor
Lab0. Get familiar with the HRM

1. Connect the board to the laptop (USB).
2. Make sure the buzzer is beeping at the same rate as your heart beats.
3. If your heart rate is greater than 100, the alarm indicator (red LED) will turn ON.
4. Go to the HRM_KA folder in the desktop and open the CodeWarrior project (HRM_KA.mcp).
5. Download the code to the board (Connect the BDM to the closest header from the KA2)
6. Go to Component → Open

Low-cost Heart Rate Monitor
Lab0. Get familiar with the HRM
7. Open the visualization tool
7. Open the HRM.vtl file
Low-cost Heart Rate Monitor
Lab0. Get familiar with the HRM

8. Run the code
9. If you never reach the value of 100 to set the alarm, change the maximum value for the alarm in the code.
Open the JM60 GUI (the shortcut is on the desktop)
Low-cost Heart Rate Monitor
Lab1. Your ECG Signal in the Computer
Low-cost Heart Rate Monitor
Lab1. Your ECG Signal in the Computer
Low-cost Heart Rate Monitor
Lab1. Your ECG Signal in the Computer
Freescale Introduces Product Longevity Program

► The embedded market needs long-term product support, which allows OEMs to provide assurance to their customers.
► Freescale has a longstanding track record of providing long-term production support for our products.
► Freescale is pleased to introduce a formal product longevity program for the market segments we serve.
  • For the automotive and medical segments, Freescale will manufacture select devices for a minimum period of 15 years.
  • For all other market segments in which Freescale participates, Freescale will manufacture select devices for a minimum period of 10 years.
► A list of applicable Freescale products is available at www.freescale.com.
Thank you for attending this presentation. We’ll now take a few moments for the audience’s questions and then we’ll begin the question and answer session.