Introduction on Patient Monitoring and Wearable Device Reference Designs
Agenda

• TI in medical
• Market trend
• Fundamentals and challenges
• Reference Designs (TIDA-01614, TIDA-010005 and etc)
TI Semiconductors in every medical category

- Medical Imaging
- Patient Monitoring & Diagnostics
- Medical Equipment
- Home Healthcare
- Personal Care & Fitness
Patient Monitoring Market Trend

- The growing elderly population drives the high demand of remote monitoring. In EU, 700B Euro spent on chronic disease per year.

- Remote monitoring enhances quality of care and reduces healthcare cost.

- Wearable wireless medical technology enables accurate and reliable data in a smaller form factor: multi-modalities, longer battery, SHIP mode.

- Artificial Intelligence uses analytics and big data to improve decision making and early prevention.
Patient Monitoring Basics

The electrocardiogram (ECG) measure of electrical activity of the heart

Photoplethysmography (PPG) is an optical measurement of an organ’s volume.
Patient Monitoring Basics

• **Pulse Transit Time (PTT)** – time interval between the R-peak of the ECG and the max slope of the PPG
• Involves simultaneous ECG and PPG measurements
• Systolic blood pressure (SBP) can be estimated from PTT
## ECG vs. PPG

<table>
<thead>
<tr>
<th>ECG</th>
<th>Feature Description</th>
<th>PPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Measurement type</td>
<td>Optical</td>
<td></td>
</tr>
<tr>
<td>Electrodes Sensor type</td>
<td>Photodiode</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Can measure heart rate?</td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>Diagnostic Information</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Minimum number of skin contacts required?</td>
<td>1 (Finger or wrist)</td>
</tr>
<tr>
<td>≥1</td>
<td>Number of ADC channels required</td>
<td>1</td>
</tr>
</tbody>
</table>
## ECG Lead and ADC Channels

**IEC60601-2-51 – Diagnostics**

<table>
<thead>
<tr>
<th>Number of Leads</th>
<th>Leads Used</th>
<th>Number of ADC Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lead I</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Lead I, Lead II, Lead III</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Lead I, Lead II, Lead III, aVR, aVL, aVF</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Lead I, Lead II, Lead III, aVR, aVL, aVF, V1 – V6</td>
<td>8</td>
</tr>
</tbody>
</table>

### Standards

<table>
<thead>
<tr>
<th>Leads</th>
<th>Electrodes Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LA, RA</td>
</tr>
<tr>
<td>3</td>
<td>LA, RA, LL</td>
</tr>
<tr>
<td>6</td>
<td>LA, RA, LL</td>
</tr>
<tr>
<td>12</td>
<td>LA, RA, LL, V1-6</td>
</tr>
</tbody>
</table>
ECG characteristics

Frequency domain

- EMG Signal: ~10mV
- ECG Signal: ~5mV
- EEG Signal: ~1mV

Frequency range:
- 0.05Hz to 10KHz
- Respiration 0 to 0.4Hz

Amplitude dependent on external current source

Frequency ranges are estimates. Actual frequency range will depend on specific application.
Challenges in measuring ECG

50/60 Hz pick-up

Alternating Current (AC) Interference
Challenges in Optical Bio-Sensing

- Low power for longer battery life
- Skin tone variation
- Best PPG signal for Motion cancellation Algorithms
- Performance with Glass
- Low temperature performance
- Ambient Light
Medical Sector Page on TI web
Medical Sensor Patches

**Temperature Analog Front End**

Temperature AFE drives the temperature sensors as well as conditions the signal coming from analog temperature sensors. The temperature signal is converted to digital domain by using ADC for further processing.

**PPG/Optical/Spectroscopy Front End**

The optical front end has two sections: one for driving the LEDs and other for processing the signal received from photo diodes. LED drivers are operated with digital data coming from DAC and trans-impedance amplifier with a PGA conditions signal coming from photo diode. This subsystem can be used for PPG as well as spectroscopy measurement.

- **TMP117** – ±0.1°C accurate digital temperature sensor with integrated 16-bit memory
- **TMP112** – 1.4V, ±0.1°C accuracy, digital temperature sensor in the compact SOT-363 package
- **TMP102** – 1.4V, ±0.3°C accuracy, digital temperature sensor with 1C/SMBus interface and Alert function in SOT-363
- **Data converters (14)**
  - **AFA4420** – Ultra-small integrated AFE with FIFO for multisensor wearable optical heart rate monitoring
  - **AFA4430** – Ultra-low-power integrated AFE for wearable optical, electrical bio-sensing

**Products** (15)

- **Products** (15)
- **Reference Designs** (17)

**Sensors (4)**

- **Reference Designs** (17)
- **Products** (15)

**Analog Temperature Sensors (1)**

**Digital Temperature Sensors (2)**

- **TMP117** – ±0.1°C accurate digital temperature sensor with integrated 16-bit memory
- **TMP112** – 1.4V, ±0.1°C accuracy, digital temperature sensor in the compact SOT-363 package
- **TMP102** – 1.4V, ±0.3°C accuracy, digital temperature sensor with 1C/SMBus interface and Alert function in SOT-363

**Data converters (14)**

- **AFA4420** – Ultra-small integrated AFE with FIFO for multisensor wearable optical heart rate monitoring
- **AFA4430** – Ultra-low-power integrated AFE for wearable optical, electrical bio-sensing
Multiparameter Patient Monitor

Multiparameter patient monitor

Multiparameter Patient Monitor integrated circuits and reference designs

<table>
<thead>
<tr>
<th>Description</th>
<th>Reference designs &amp; products</th>
<th>Technical documents</th>
<th>Support &amp; training</th>
</tr>
</thead>
</table>

**Description**

Our integrated circuits and reference designs help you create highly accurate multiparameter patient monitors to meet system design requirements while minimizing power consumption.

Innovative multiparameter patient monitors require:

- Precise, multi-parameter measurements with high sensitivity
- Wireless, secure connectivity for data logging and monitoring
- Intuitive, responsive human machine interface (HMI)

**Analog front end**

The AFE digitizes the heart signal after signal conditioning the signal. It includes multiplexer, instrumentation amplifier, filter, ADC. Additionally, it includes temperature sensor, respiratory circuit, pacemaker detection and lead off detection circuit.

**REFERENCE DESIGNS (0)**

**PRODUCTS (0)**

- Multiparameter front end reference design for vital signs patient monitor
  - Schematic/Block diagram
  - Reference guide
  - View reference design

**Alarm tone generator reference design**

**Software-Configurable Cardiac Pacemaker Detection Module Reference Design**

**Texas Instruments**
TIDA-01614
Multiparameter front-end for vital signs patient monitor reference design

Features

- System measures ECG, Heart Rate, SPO2, Respiration rate using ADS1292R and AFE4403 and Skin temperature using TMP117
- Circuit enables three electrode operation including right leg drive with good CMRR
- Pace detection circuit indicates presence of pacemaker
- Supports three 0.1 Celsius accurate sensors (TMP117) to measure the skin temperature
- Enables data transfer over isolated UART interface
- Works with 3.7V Li ion rechargeable battery
- On board memory for data logging

Benefits

- Single IC does both ECG, Respiration
- Pace Detection
- ECG with 3 electrodes
- Three temperature sensors for temperature measurement

Applications

- Multiparameter Patient Monitor
- Medical Sensor Patches
- Pulse Oximeter
- Electrocardiogram (ECG)
Design Challenges TIDA-01614 Solves

**Design Challenge 1:**
Integration of multiple modalities at optimum SNR levels and small form factor

- Monitoring of ECG, Heart Rate, SPO2, PTT, Respiration rate and Skin temperature
- Single Lead ECG with RLD (ADS1292R)
  - Signal amplitude: 0.2mV~2mV (p-p);
  - BW 0.05 Hz to 2000 Hz
- Supports 3 LED and 3 Photodiodes with ambient subtraction for SPO2 and Heart Rate monitoring with AFE4403
- Supports three 0.1 Celsius accurate sensors to measure the skin temperature (TMP117)

**Design Challenge 2:**
Protection and isolation against ESD & defibrillation per IEC 60601-1-2

- Using TVS0500 and series current limit resistor. TVS0500 has lower clamping voltage to protect ADS1292R.
- Isolated UART interface using an onboard MSP432P401, ISOW7842, TRS3232
ECG Analog Front End

Important Parameters:
- Input Bias Current
- Input Impedance
- Input Current Noise
- Input Voltage Noise
- Power Consumption
- DC/AC CMRR

TIDA-01614: Multiparameter front-end reference design for vital signs patient monitor
TIDA-01614 Test Setup and Test Results

Design Specs

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG</td>
<td>One lead ECG operation with RLD. Sampling rate of 500 samples per second, supports ECG sensitivity of 100 μV</td>
</tr>
<tr>
<td>SPO2 Measurement</td>
<td>Works in transmissive SPO2, refresh rate of 500 Hz</td>
</tr>
<tr>
<td>Skin Temperature Measurement</td>
<td>Three temperature sensor with 0.1 degree accuracy</td>
</tr>
<tr>
<td>Pace pulse Rise-time (TR) measurement range</td>
<td>30–200 μs</td>
</tr>
<tr>
<td>Pace pulse duration (TD) measurement range</td>
<td>0.1–2 ms</td>
</tr>
<tr>
<td>Input Pace signal amplitude range</td>
<td>8 mV–700 mV</td>
</tr>
<tr>
<td>Input Voltage (Vin)</td>
<td>5 V from Micro-USB</td>
</tr>
</tbody>
</table>

Test Setup

GUI Display
ADS1291/2
ADC specifications

- Low-noise, high input impedance front end PGAs
- 24-bit simultaneous sampling delta-sigma ADCs (data rates 125 SPS – 8 kSPS)
- 8 μV pk-pk noise (PGA gain = 6, BW = 150 Hz)
- CMRR: -105 dB
- Integrated Right-Leg Drive amplifier
- Integrated Lead-off detection
- Integrated respiration impedance measurement (ADS1292R)
- Integrated test signals for verification
- Integrated low-drift ADC reference
- Integrated oscillator
Clinical ECG Portfolio

Number of Channels

8

7

6

5

4

3

2

1

ADS1198
16-bit, 8kSPS

ADS1298
24-bit, 32kSPS

ADS1298R
24-bit, 32kSPS

ADS1299
24-bit, 16kSPS

ADS1196
16-bit, 8kSPS

ADS1296
24-bit, 32kSPS

ADS1296R
24-bit, 32kSPS

ADS1194
16-bit, 8kSPS

ADS1294
24-bit, 32kSPS

ADS1294R
24-bit, 32kSPS

ADS1293
24-bit, 6.4kSPS

ADS1192
16-bit, 2kSPS

ADS1292
24-bit, 2kSPS

ADS1292R
24-bit, 2kSPS

ADS1191
16-bit, 2kSPS

ADS1291
24-bit, 2kSPS

16-bit

Resolution

24-bit

Integrated Respiration impedance measurement

Texas Instruments
**TIDA-010005/Software-Configurable Cardiac Pacemaker Detection Module Reference Design**

**Features**
- Programmable Thresholds for detecting rise time, amplitude, duration and polarity of pace pulse
- Availability of measured parameters and conditioned pace signal on I²C Bus for further analysis and processing
- Interface with TI’s ADS129X series of ECG front end devices
- Detection of negative pulse by handling polarity of pace pulse by software command

**Benefits**
- Detection of various types of pacemaker pulse provides the user one stop solution
- Modular approach compatible with other patient monitoring TI Designs such as TIDA-01614
- Compact form factor
- A flag signal and onboard LED are the indication of presence of ‘valid’ pace signal.

**Applications**
- Multi-parameter Patient Monitor
- Medical Sensor Patches
- Electrocardiogram (ECG)

**Tools & Resources**
- TIDA-010005 and Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software.

**Device Datasheets:**
- INA317
- TLV9062
- TLV1702
- DAC5578
- ADS7142

**Detectors of various types of pacemaker pulse provides the user one stop solution**
- Modular approach compatible with other patient monitoring TI Designs such as TIDA-01614
- Compact form factor
- A flag signal and onboard LED are the indication of presence of ‘valid’ pace signal.
Design Challenge: Low noise, highly integrated signal path for ECG with lead-off and pace detection:
to detect amplitude, rise time, width and polarity for diagnostics with different makes of Pacemaker

- Pace signals have specific characteristics:
  Amplitude: 2 mV to 700 mV
  Rise Time: 10 µs to 200 µs
  Pulse Duration: 100 µs to 2 ms
  Polarity: +Ve or -Ve
- Major difficulty comes due to the small amplitude, narrow-width and varying slope of
  the pulse accompanied with noise consisting of: the ECG signal itself, noise from muscle
  movement due to beating of heart and breathing, 50/60 Hz pickup from the surroundings
Proposed Solution

In order to define a ‘valid’ pace pulse, the system discriminates various signals by comparing it to the user defined thresholds. The criteria for the same is:

- **Amplitude >** $V_{Amp\_th}$
- $V_{RT\_min} < \text{Rise Time Measure (} V_{RT} \text{)} < V_{RT\_max}$
- $V_{PT\_min} < \text{Pulse Duration Measure (} V_{PT} \text{)} < V_{PT\_max}$

$V_{Amp\_th}, V_{RT\_min}, V_{RT\_max}, V_{PT\_min} \text{ and } V_{PT\_max}$ comes from the DAC
Negative Pace Signal Detection - Negative Pace Pulse Undetected

Negative Pace Signal Detection Negative Pace Pulse Detected by setting the DACs Polarity Check (CH 6) Output High
Test Pacemaker Detection with TIDA-010005 & TIDA-01614
TIDA-01580 Wearable, Wireless, Multi-Parameter Patient Monitor Reference Design

Features

- Simple Wearable Multi-Parameter Patient Monitor for Photoplethysmography (PPG) and Electrocardiography (ECG)
- Provides Raw data to calculate heart-rate, Oxygen Concentration in Blood (SpO2) and Pulse-transit Time (PTT)
- Uses Single-chip Bio-sensing Front-End AFE4900 for Synchronized ECG & PPG
  - PPG (Optical heart-rate monitoring and SpO2) supports 4 LEDs and 3 PDs with Digital Ambient subtraction to improve the SNR
  - ECG (LEAD I) signals
- Integrated ARM Cortex-M3 + 2.4GHz RF Transceiver (CC2640R2F) supports wireless data transfer – BLE 4.2 and 5
- Operated from CR3032 (3V, 500mA Coin Cell Battery) with battery life of 30 days using highly efficient DC/DC converters
- Small form factor helps in easy adaptation to wearable applications

Benefits

- PPG supports 4 LEDs and 3 PDs with Digital Ambient subtraction to improve the SNR
- AC and DC lead off detection helps in correct measurement of vital signs
- Continuous Monitoring with lower operating power ensures battery life of 30 days
- Flexibility of ultra low power modes and integrated FIFO can keep MCU into sleep to increase the battery operation time

Target Applications

- Wireless Patient Monitor
- Pulse Oximeter
- Wearable Fitness & Activity Monitor
- ECG

Tools & Resources

- Device Datasheets:
  - AFE4900 - CC2640R2F
  - TPS61098 - TPS63036
  - TPD1E10B06

Copyright © 2018, Texas Instruments Incorporated
TIDA-01580 Medical Patches

This board is connected on bottom of the main board.

This side is touching the wrist of one hand (ELECTRODE 1)

Other hand can be touched on PAD on top layer of the main board. (ELECTRODE 2)

Side View

- LAUNCHXL-CC2640R2F receives the signals remotely and displays on LabView GUI
- The design uses BLE 5.0 with an advertising time = 100ms
Design Challenges TIDA-01580 Solves

### Design Challenge #1:
**Integration of multiple modalities at optimum SNR levels and small form factor**

- Capturing synchronized ECG and PPG to enable PTT and BP calculations (non-invasive and without cuff)
- Pulse Transit Time (PTT): Time difference between the R-peak in the ECG waveform and the arrival of the blood pressure wave
- Simultaneous measurement of ECG and PPG together
- Along with other variables, such as the patient’s size, weight, age, etc., algorithms show the correlation between PTT and systolic blood pressure.
- Challenging to synchronize both measurements – timing is the key! (Powering up, clock timing, phase, drift with temperature)
Design Challenges TIDA-01580 Solves

Design Challenge # 2:
BLE connectivity that does not interfere with measurement accuracy

- Signal amplitude: 0.2mV to 2mV (p-p)
- BW : as broad as 0.05 Hz to 300 Hz (Pace detection increases the bandwidth further)
- Reject environmental electrical signals, such as ac mains, security systems, and RFI to amplify and display the ECG signal
- Good CMRR of the signal chain and Right-leg drive (RLD) for CM rejection
- Differential- and common-mode filtering, environmental shielding, and algorithms
Design Challenges TIDA-01580 Solves

Design Challenge # 3:
Extending battery life to multiple days to enable portability & wearability

- Selecting the right power architecture to enable extended battery life up to 24 hours (for rechargeable batteries) or 7 days (for primary cells)
- Powering with right buck, boost or buck-boost device instead of directly powering from battery (bypass modes in DC/DC converters)
- Sleep / shutdown / standby / deep sleep modes for radio devices like BLE, Wi-Fi etc.
- Selection of right battery charger (charging rate, termination current and quiescent currents are important!)
SHIP mode

- By definition: Ship mode electronically disconnects the battery from the rest of the system to minimize power drain while the product is idle. When the consumer turns the product on for the first time, the battery connects to the rest of the system and stays connected until the system decides to put itself back into ship mode.

- Existing TI collaterals:
  - Implementing Ship Mode Using the TPS22915B Load Switch
  - Don’t let your battery drain on the shelf – use ship mode
  - Ship mode reference design (TIDA-00556)
Low-voltage switchers

- For battery operated patches, a buck-boost and/or a boost is required. Few proposed devices are:

<table>
<thead>
<tr>
<th></th>
<th>TPS63802</th>
<th>TPS63030</th>
<th>TPS63036</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin (Min) (V)</td>
<td>1.3</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Vin (Max) (V)</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Vout (Min) (V)</td>
<td>1.8</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Vout (Max) (V)</td>
<td>5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Iout (Max) (A)</td>
<td>2</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Rating</td>
<td>Catalog</td>
<td>Catalog</td>
<td>Catalog</td>
</tr>
<tr>
<td>Topology</td>
<td>Buck-Boost</td>
<td>Buck-Boost</td>
<td>Buck-Boost</td>
</tr>
<tr>
<td>Type</td>
<td>Converter</td>
<td>Converter</td>
<td>Converter</td>
</tr>
<tr>
<td>Switching frequency (Min) (kHz)</td>
<td>2500</td>
<td>2200</td>
<td>2200</td>
</tr>
<tr>
<td>Switching frequency (Max) (kHz)</td>
<td>2500</td>
<td>2600</td>
<td>2600</td>
</tr>
<tr>
<td>Iq (Typ) (mA)</td>
<td>0.011</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>Features</td>
<td>Enable</td>
<td>Enable</td>
<td>Enable</td>
</tr>
<tr>
<td></td>
<td>Light Load Efficiency</td>
<td>Light Load Efficiency</td>
<td>Light Load Efficiency</td>
</tr>
<tr>
<td></td>
<td>Load Disconnect</td>
<td>Load Disconnect</td>
<td>Load Disconnect</td>
</tr>
<tr>
<td></td>
<td>Power Good</td>
<td>Power Good</td>
<td>Power Good</td>
</tr>
<tr>
<td></td>
<td>Pre-Bias Start-Up</td>
<td>Pre-Bias Start-Up</td>
<td>Pre-Bias Start-Up</td>
</tr>
<tr>
<td></td>
<td>Synchronous Rectification</td>
<td>Synchronous Rectification</td>
<td>Synchronous Rectification</td>
</tr>
<tr>
<td></td>
<td>UVLO Fixed</td>
<td>UVLO Fixed</td>
<td>UVLO Fixed</td>
</tr>
<tr>
<td>Switch current limit (Typ) (A)</td>
<td>4.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Duty cycle (Max) (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Operating temperature range (C)</td>
<td>-40 to 125</td>
<td>-40 to 85</td>
<td>-40 to 85</td>
</tr>
<tr>
<td>Package Group</td>
<td>VSON-HR</td>
<td>SON</td>
<td>DSBGA</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>TPS61022</th>
<th>TPS61099</th>
<th>TPS61291</th>
<th>LMR61428</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin (Min) (V)</td>
<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Vin (Max) (V)</td>
<td>5.5</td>
<td>5.5</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Vout (Min) (V)</td>
<td>2.2</td>
<td>1.8</td>
<td>2.5</td>
<td>1.24</td>
</tr>
<tr>
<td>Vout (Max) (V)</td>
<td>5.5</td>
<td>5.5</td>
<td>3.3</td>
<td>14</td>
</tr>
<tr>
<td>Switch current limit (Typ) (A)</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>2.85</td>
</tr>
<tr>
<td>Switching frequency (Min) (kHz)</td>
<td>1000</td>
<td>2300</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Switching frequency (Max) (kHz)</td>
<td>1000</td>
<td>3000</td>
<td>2300</td>
<td>2000</td>
</tr>
<tr>
<td>Iq (Typ) (mA)</td>
<td>0.027</td>
<td>0.0008</td>
<td>0.005</td>
<td>0.1</td>
</tr>
<tr>
<td>Features</td>
<td>Enable</td>
<td>Synchronous Rectification</td>
<td>Bypass Mode</td>
<td>Enable</td>
</tr>
<tr>
<td></td>
<td>Light Load Efficiency</td>
<td>Synchronous Rectification</td>
<td>Enable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Load Disconnect</td>
<td>Load Disconnect</td>
<td>Load Disconnect</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-Bias Start-Up</td>
<td>Pre-Bias Start-Up</td>
<td>Pre-Bias Start-Up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Synchronous Rectification</td>
<td>Synchronous Rectification</td>
<td>Synchronous Rectification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UVLO Fixed</td>
<td>UVLO Fixed</td>
<td>UVLO Fixed</td>
<td></td>
</tr>
<tr>
<td>Duty cycle (Max) (%)</td>
<td>97</td>
<td>90</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>Package Group</td>
<td>VSON-HR</td>
<td>SON</td>
<td>DSBGA</td>
<td>8</td>
</tr>
</tbody>
</table>

*Texas Instruments*
Full system | Multi-parameter patient monitor + wireless sensors

Nurse’s Station / Doctor’s Office
Why TI SimpleLink™ for Multi-parameter patient monitor + sensor patch?

- **Low Power**
  - BLE SoC with integrated Ultra low Power Sensor Controller
  - Wi-Fi low power IoT
  - Best-in-class standby current

- **Ease of use**
  - CC3135/CC3235 Wi-Fi modules
  - 5GHz Wi-Fi to reliably connect to hospital network
  - BLE multi-role support *up to 32 simultaneous connections*

- **Secure**
  - FIPS 140-Level 1 validation
  - Offload CPU bandwidth – HW crypto accelerators
  - Secure boot

- **Small size**
  - BAW: First crystal-less wireless BLE SoC
  - 12% area savings in reference design
  - Tiny BLE SoC: CC2640R2F
  - 2.7mmx2.7mm DSBGA
Invest once, reuse effortlessly

- Learn more about SimpleLink code portability
- SimpleLink Medical Resources
TIDA-010029
Wearable, 16-phase multi-sensor SpO2 and heart rate monitor (HRM) reference design with Bluetooth® 5

Features

- Provides raw data to calculate heart rate, SpO2, and other related parameters
- Uses single-chip, bio-sensing, front-end AFE4420 device for PPG measurement
  - Enables signal acquisition of up to 16 phases and multi-wavelength measurements with the flexible allocation of LEDs and photodiodes in each phase
- Integrated Arm® Cortex®-M3 and 2.4-GHz RF transceiver (CC2640R2F) supports wireless data transfer through Bluetooth® low energy 4.2 and 5.0

Benefits

- PPG supports 4 LEDs and 4 PDs with Automatic Ambient subtraction to improve the SNR
- Continuous Monitoring with lower operating power ensures battery life of 100 hours for continuous operation
- Flexibility of ultra low power modes and integrated FIFO can keep MCU into sleep to increase the battery operation time
- Small form factor helps in easy adaptation to wearable applications

Applications

- Pulse Oximeter
- Wearable Fitness and Activity Monitor
- Multiparameter Patient Monitor
- Medical Sensor Patches

Tools & Resources

- TIDA-010029 and/or Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software, etc.

Device Datasheets:
- AFE4420
- CC2640R2F
- TPS63036
- TPS61099
- TPD1E10B06

Copyright ©2016 Texas Instruments Incorporated
Design Challenges TIDA-010029 Solves

Design Challenge # 1:
Integration of multiple modalities at optimum SNR levels and small form factor

- Provides raw data to calculate heart rate, SpO2, and other related parameters
- Supports 4 LEDs and 4 PDs with improved SNR
- External Light sources can disturb the receive signal (Smart automatic ambient light suppressing technologies – integrated into the device)
- Standard pulse oximetry uses Red and IR lights. The additional green and orange wavelengths can distinguish to the absorption of deoxyhemoglobin (RHb) and oxyhemoglobin (HbO2).
- Physiology of the Human body (Skin tone and body Location determines use case, Transmissive vs reflective oximetry)

Source: An applicable approach for extracting human heart rate and oxygen saturation during physical movements using a multi-wavelength illumination optoelectronic sensor system (Link)
Design Challenges TIDA-010029 Solves

Design Challenge # 2: BLE connectivity that does not interfere with measurement accuracy

- Supports wireless data transfer through Bluetooth® low energy 4.2 and 5.0 with CC2642R
- CM chokes placed at the PD inputs to reduce noise effects on very sensitive signals coming from photo diodes
- Layout Optimization for AFE and BLE to minimize interface while maintain the measurement accuracy
- AFE4420 and CC2640R2F placed on different layers with GND layer in between for shielding
- Split ground for RF and AFE sections
- STAR grounding at the negative terminal of the battery
TIDA-010029 board details
**TIDA-010043: Efficient, high-current, linear LED driver reference design for SpO2 and other medical applications**

### Features

- Higher efficiency by providing headroom control to optimally drive LED
- Diagnostics (LED open, LED short, LED disconnect) and protection mechanism for fault by disconnecting the supply using e-fuse
- Wide operating input range from 1.8 V to 5.5 V to support all battery type inputs
- Programmable range selection for LED current (from 100 mA to 1.5 A)
- Compatible with AFE44xx series EVMs (tested with AFE4403 EVM) for driving LEDs
- Tested with MSP430G2553 LAUNCHPAD™ and two on-board LEDs (green and red)

### Benefits

- Built-in self-calibration and look-up table for headroom control
- Dynamic adjustment of the LED supply voltage, to achieve optimal efficiency at the programmed current levels

### Target Applications

- Pulse oximeter
- Multiparameter patient monitor
- Endoscope
- Surgical equipment

### Tools & Resources

Device datasheets:
- TPS63802
- TPS2595
- TPS2595
- CSD13306W
- CSD1320Q2
- TMUX1119
- TLV7021
- OPA333
- OPA365

---

**Texas Instruments**
Design Challenges TIDA-010043 solves

Design Challenge: Accurate SpO2 measurement across varying photodiode placements, wavelengths and body physiologies through optimizing LED driving circuit and photo-diode signal chain at low power.

- External Light sources are disturbing the receive signal (Smart ambient light suppressing technologies – integrated into the device)
- Physiology of the Human body (Skin tone and body Location determines use case, Transmissive vs reflective oximetry)
- Optical Signal Path (Define optimal Photo Diode size & LED wavelengths, use multiple sensors and PDs, optimum in PD / LED spacing)
These are number of steps for calibration

These are course and fine levels for setting the PWM to set the LED supply voltage (Each step in calibration has to go through course and fine level adjustment)

Check FET_SAT to confirm if the step is over and to go to next step in calibration
4.7V

TPS63802 Vout (LED Supply Voltage)

FET_SAT signal (used for sensing if the LED current is gone out of linear region)

Software steps for calibration (the current through LED will increase by 100mA for each step)

No. of steps for calibration

Each calibration step has course and fine levels for setting the LED supply voltage

Software steps for calibration (the current through LED will increase by 100mA for each step)
Calibration loop
### TIDA-01624 Bluetooth-Enabled High Accuracy Skin Temperature Measurement Flex PCB Patch

#### Features
- High Accuracy, Low Power Temperature Sensor
- BLE 4.2 and 5 enabled microcontroller
- Thin-Film Flexible Battery Power, enabling entirely flexible design
- Integrated PCB antenna
- Temperature updates every second

#### Benefits
- Low power consumption and long battery life
- Extremely long shelf life (3+ Years)
- Small, Flexible Form Factor
- Connects to Smart Device
- Zero-Calibration to ±0.1°C Accuracy

#### Applications
- Medical Sensor Patches
- Multiparameter Patient Monitors
- Smart Patches

#### Tools & Resources
- TIDA-01624 and/or Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software, etc.

#### Device Datasheets:
- TMP117
- CC2640R2F

---

![Diagram of Skin Temperature Measurement Flex PCB Patch](image)
TMP117x
Ultra-High Accuracy Digital Temp Sensor with integrated non-volatile memory

Features

<table>
<thead>
<tr>
<th>TI Part</th>
<th>Accuracy (°C)</th>
<th>Accuracy Full Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMP117M</td>
<td>±0.1°C @ (30°C to 45°C)</td>
<td>±0.2°C @ (0°C to 85°C)</td>
</tr>
<tr>
<td>TMP117</td>
<td>±0.1°C @ (-20°C to 50°C)</td>
<td>±0.3°C @ (-55°C to 150°C)</td>
</tr>
<tr>
<td>TMP117N</td>
<td>±0.2°C @ (-40°C to 100°C)</td>
<td>±0.3°C @ (-55°C to 150°C)</td>
</tr>
</tbody>
</table>

- 16-bit Resolution (0.0078°C)
- Minimum PSRR: 1LSB = 7.8 m°C/V

Integrated EEPROM

Low power consumption
- 140µA Iq during conversion
- 3.5µA Average Iq @ 1Hz
- 150nA Shutdown Iq
- 1.8V – 5.5V

Digital feature: Automatic offset NVM/ Soft Reset

Interface: Single wire

Packaging
- 6pin WSON (2 x 2) mm
- 6pin WCSP (1.6 x 1) mm

Applications
- Gas Meter
- Medical
- Cold Chain
- Wearables
- Instrumentation & Test
- Thermocouple – Reference

Benefits

Ultra-high Accuracy
- Meets ASTM E1112 & ISO medical standards:
  - 0.1°C acc. range 35.8°C to 42°C
- No calibration needed; NIST Traceable

Integrated Non-volatile memory
- Store configuration even after losing power
- 64 Bits of general purpose scratch pad memory

Low Power Consumption
- 3.5µA Average Iq @ 1Hz; serial bus inactive
- 150nA Shutdown Iq; serial bus inactive

Digital feature & I2C Interface:
- Programmable Temperature Alert & Offset value
- Soft Device Rest

Smallest Package: 6 PIN, QFN & CSP
TIDA-010040 / Alarm tone generator reference design

Features

• Provides a solution that can be used for producing auditory alarms described in the IEC60601-1-8 medical specification.
• Capable of outputting low, medium, and high priority alarms with software-adjustable rise/fall time, pulse duration, pulse spacing, and burst spacing.
• Can output 8 different alarm melodies as described in the IEC60601-1-8 spec.
• Coincidence Detector confirms if speaker is actually making correct sound.

Benefits

• Timing parameters are all adjustable via firmware.
• Minimal code-space used allows for low-cost MSP430.
• Booster pack design makes for easy setup.

Target Applications

• Multiparameter Patient Monitor
• Dialysis Machine
• AED
• Infusion Pump
• Surgery Equipment
IEC60601-1-8 based medical alarm tone generation & coincidence detection

- Provides a solution that can be used for producing auditory alarms described in the IEC60601-1-8 medical specification.

- With a Low cost microcontroller and some external hardware, Analog Burst patterns are created. The Rise and Fall times, the Amplitude, width and Frequency of these Bursts are all programmable.

- The Alarm made by the circuit when attached to a Patient monitor might be indicative of a Medical condition such as a Heart attack. Therefore it is very important that the Alarm itself has some kind of monitoring of its operation.

A microphone is placed close to the speaker and it monitors the sounds made by the Alarm. If the Actual sound received by the microphone is not the same as the sound intended by the circuit an error flag is raised. This is called Coincidence detection.
TIDA-010040 – Coincidence Detection

Burst Waveform

Speaker

Coincidence Circuit - asserts when electrical waveform driving speaker matches received signal by Mic

Mic

Envelope of Mic Signal

Speaker Drive
Welcome to the TI E2E™ Community
Find answers to your technical questions

Search E2E by part number and/or keyword. (e.g. OPA333 output peaking)

2,785 Contributing TI employees
295,218 Issues resolved

Recent activity

TLV320ADC33EVHM-K: Audio Serial Data Bus
Part Number: TLV320ADC33EVHM-K
Hi all, I have to read two stereo channels, so two I2S outputs A and B of the Codec are used. Both I2S A and B outputs are connected to an FPGA on two IP I2S. Is it possible to read I2S_A (Audio Serial Data Bus A) and I2S_B (Audio Serial Data Bus B) outputs simultaneously? That means both I2S outputs are independent, no data multiplexed? Best regards, Pa...
IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated