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

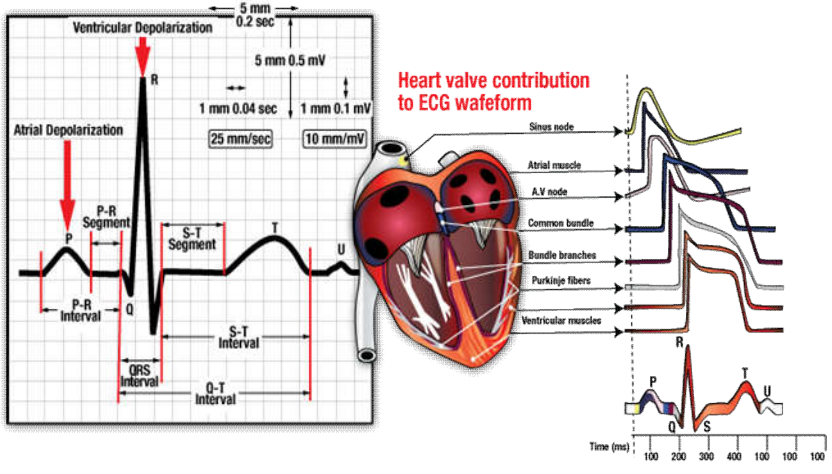
Medical Imaging	Patient Monitoring & Diagnostics	Medical Equipment	Home Healthcare	Personal Care & Fitness
				

Patient Monitoring Market Trend

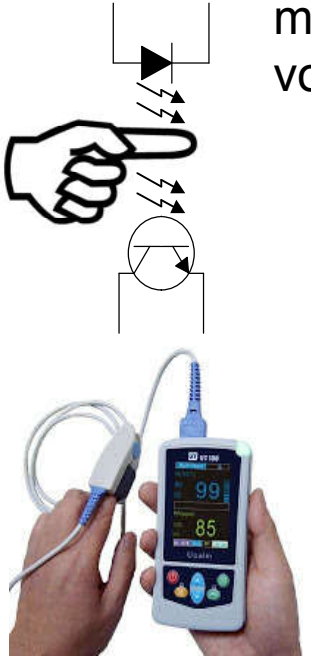
- The growing elderly population drives the high demand of remote monitoring- In EU, 700B Euro spent on chronic disease per year
- Remote monitoring enhances quality of care and reduces healthcare cost
- Wearable wireless medical technology enables accurate and reliable data in a smaller form factor: multi-modalities, longer battery, SHIP mode
- Artificial Intelligence uses analytics and big data to improve decision making and early prevention

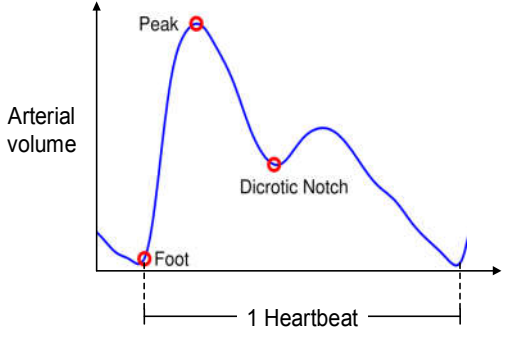
Patient Monitoring Basics

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



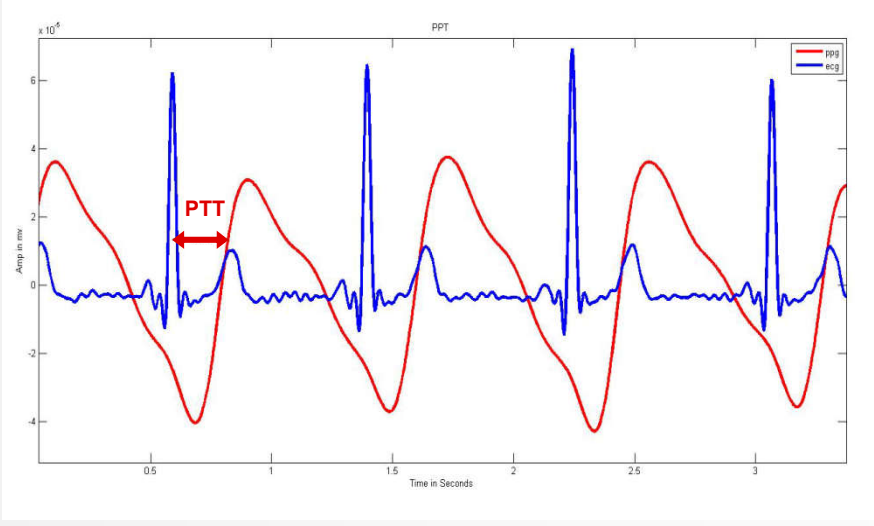
Photoplethysmography (PPG) is an ***optical*** measurement of an organ's volume.





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

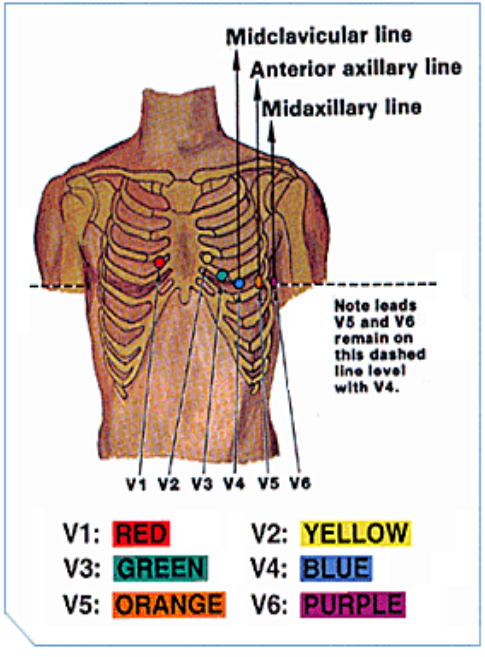
ECG	Feature Description	PPG
Electrical	Measurement type	Optical
Electrodes	Sensor type	Photodiode
Yes	Can measure heart rate?	Yes
Yes	Diagnostic Information	Yes
2 (Across chest)	Minimum number of skin contacts required?	1 (Finger or wrist)
≥1	Number of ADC channels required	1

ECG Lead and ADC Channels

IEC60601-2-51 – Diagnostics

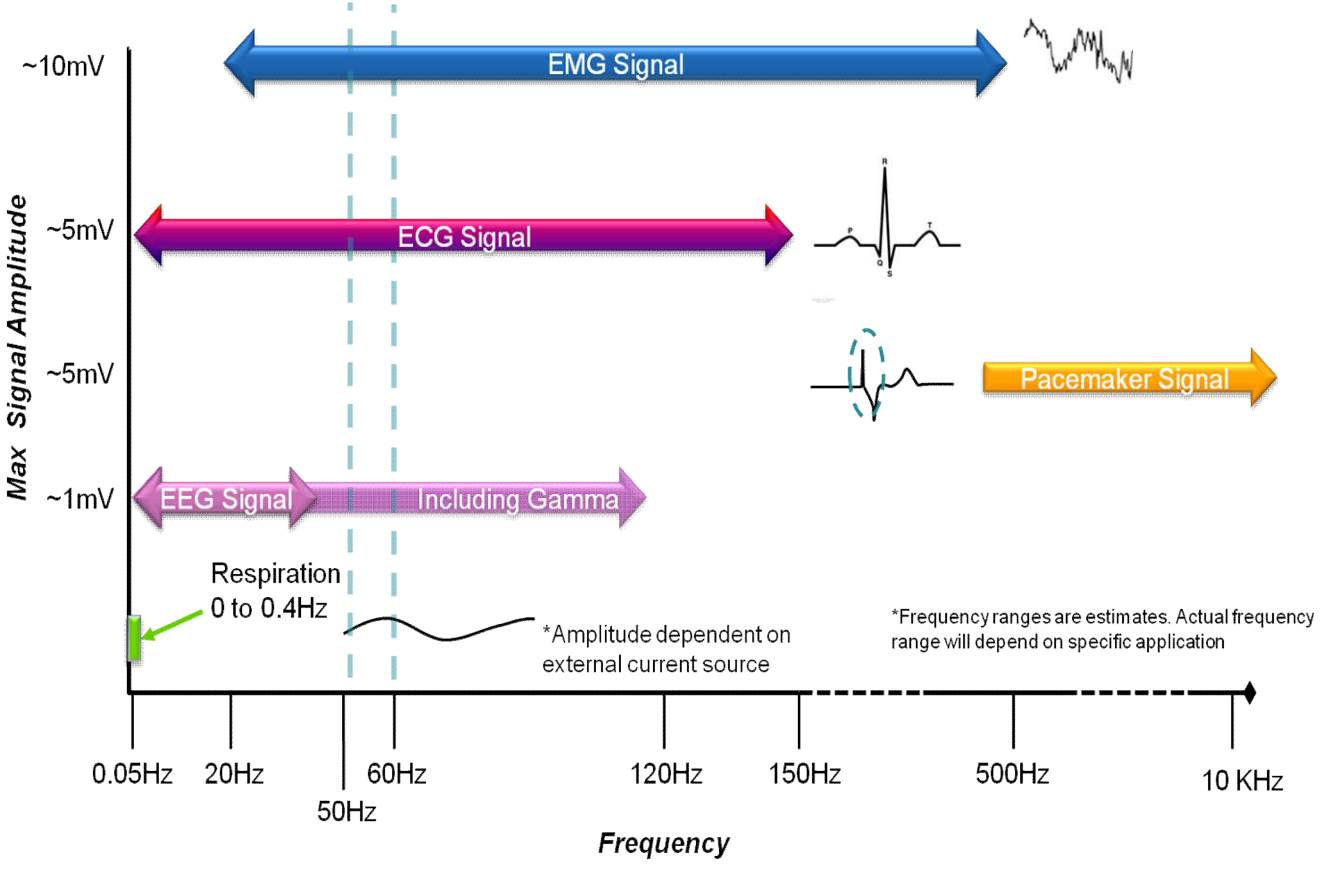
Number of Leads	Leads Used	Number of ADC Channels
1	Lead I	1
3	Lead I, Lead II, Lead III	2
6	Lead I, Lead II, Lead III, aVR, aVL, aVF	2
12	Lead I, Lead II, Lead III, aVR, aVL, aVF, V1 – V6	8

Standards	Electrodes Needed
1 Lead	LA, RA
3 Lead	LA, RA, LL
6 Leads	LA, RA, LL
12 Leads	LA, RA, LL, V1-6



ECG characteristics

Frequency domain



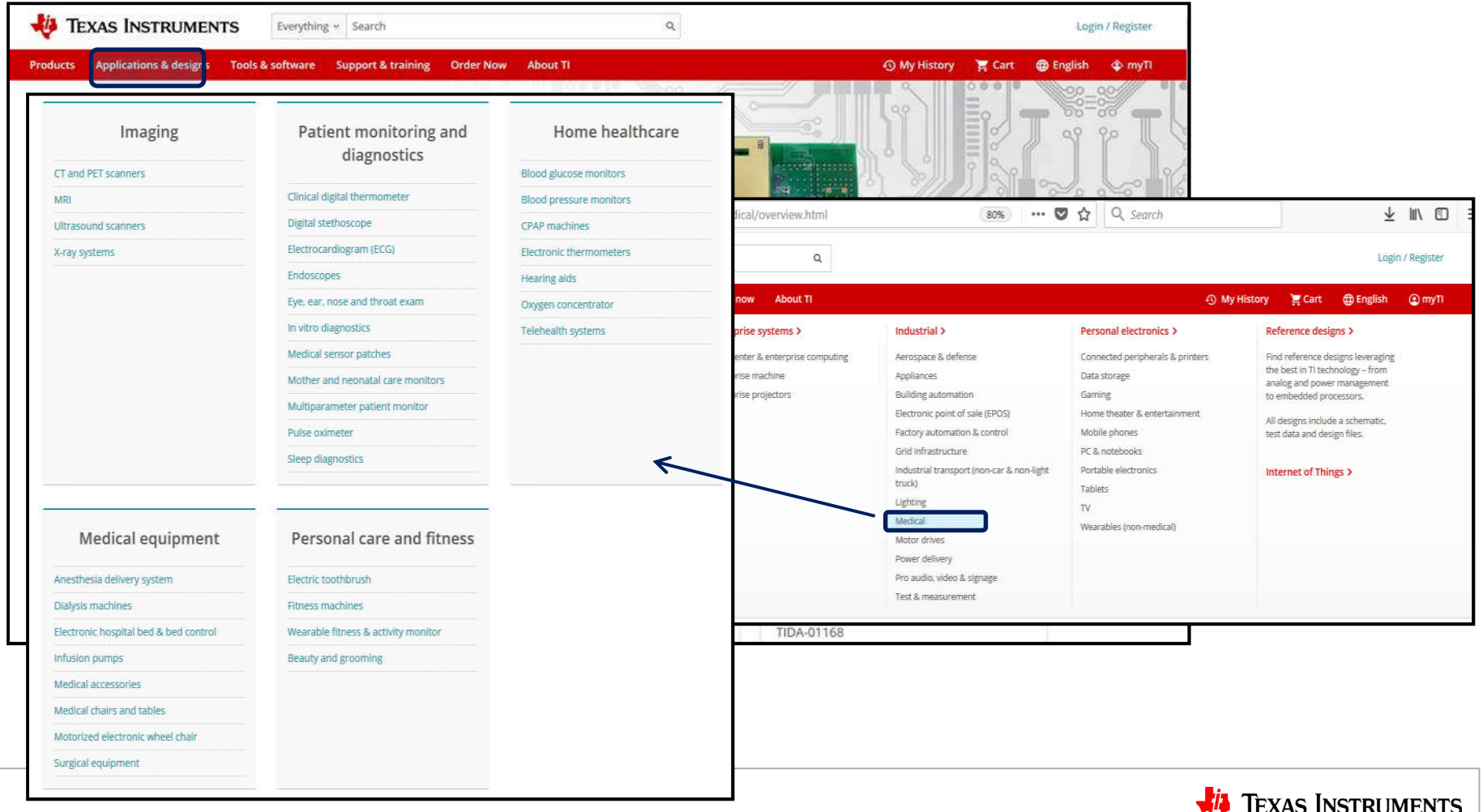
Challenges in measuring ECG

Alternating Current (AC) Interference

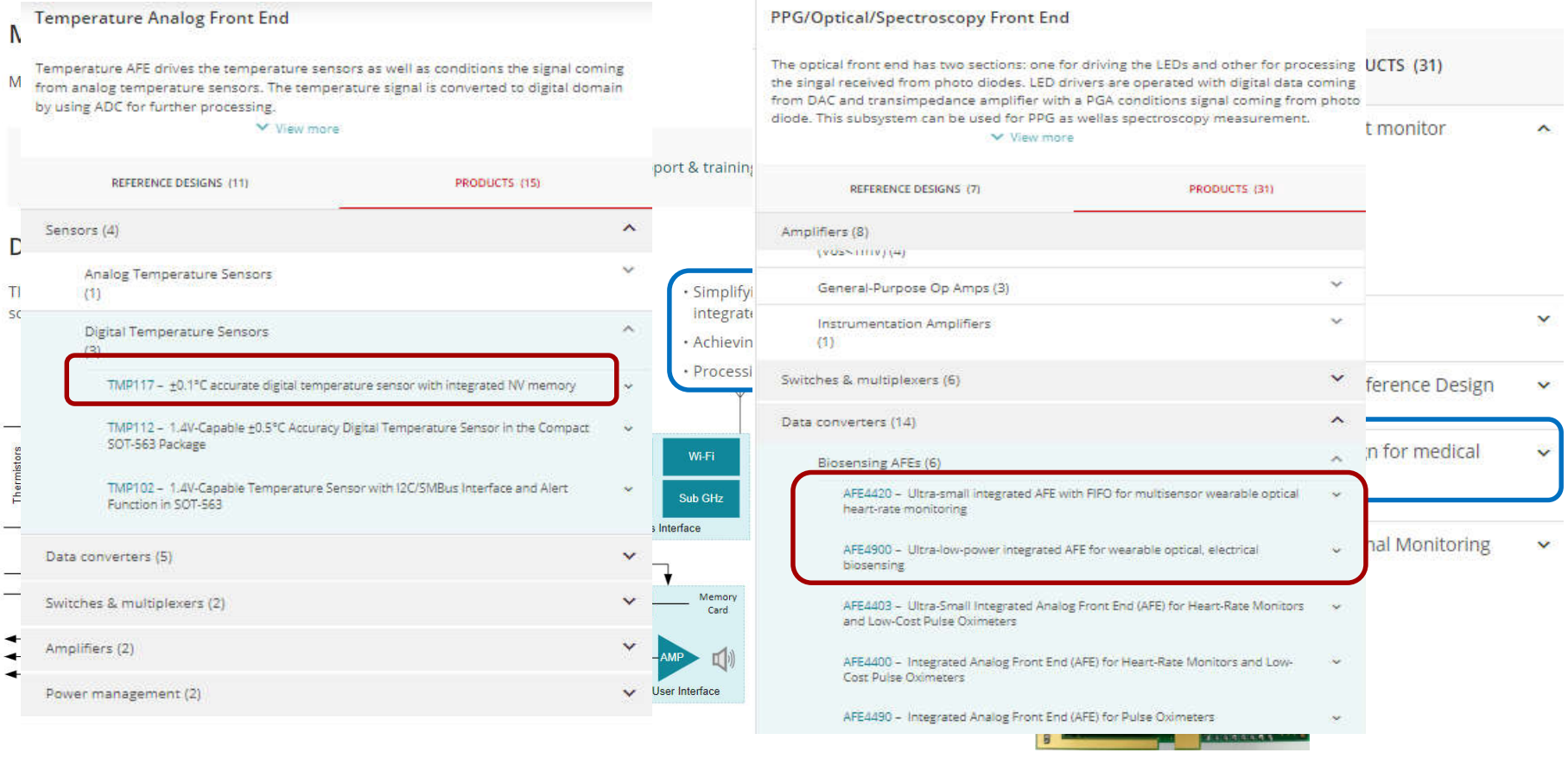
Challenges in Optical Bio-Sensing

- 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



Multiparameter Patient Monitor

Multiparameter patient monitor

Multiparameter Patient Monitor integrated circuits and reference designs

Description | Reference designs & products | Technical documents | Support & training

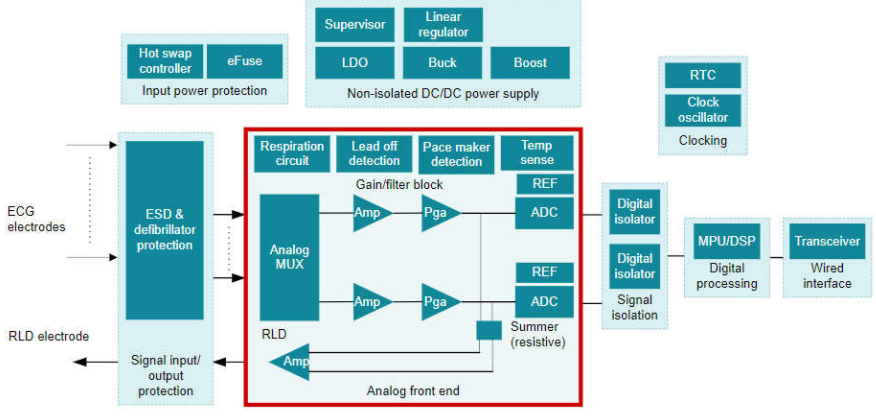
Description

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)

Select a subsystem for: Patient monitor - ECG module



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.

View more

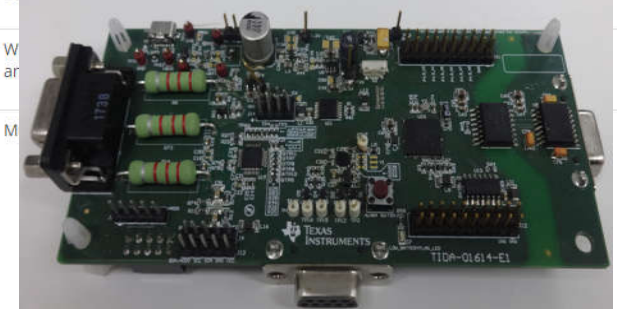
REFERENCE DESIGNS (9) PRODUCTS (50)

Multiparameter front end reference design for vital signs patient monitor

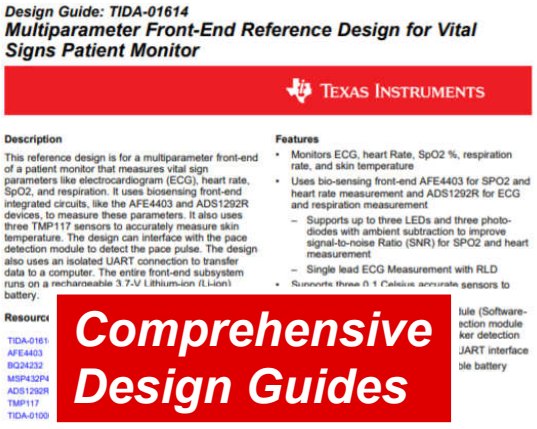
Schematic/Block diagram
Reference guide
View reference design

Alarm tone generator reference design

Software-Configurable Cardiac Pacemaker Detection Module Reference Design



Reference Design



Design Guide: TIDA-01614
Multiparameter Front-End Reference Design for Vital Signs Patient Monitor

Texas Instruments

Description

This reference design is for a multiparameter front-end of a patient monitor that measures vital sign parameters like electrocardiogram (ECG), heart rate, SpO2, and respiration. It uses biosensing front-end integrated circuits, like the AFE4403 and ADS1292R devices, to measure these parameters. It also uses three TMP117 sensors to accurately measure skin temperature. The design can interface with the pace detection module to detect the pace pulse. The design also uses an isolated UART connection to transfer data to a computer. The entire front-end subsystem runs on a rechargeable 3.7-V Lithium-ion (Li-ion) battery.

Features

- Monitors ECG, heart Rate, SpO2 %, respiration rate, and skin temperature
- Uses bio-sensing front-end AFE4403 for SPO2 and heart rate measurement and ADS1292R for ECG and respiration measurement
  - Supports up to three LEDs and three photo-diodes with ambient subtraction to improve signal-to-noise Ratio (SNR) for SPO2 and heart measurement
  - Single lead ECG Measurement with RLD
- Supports three 0.1 Celsius accurate sensors to

Resources

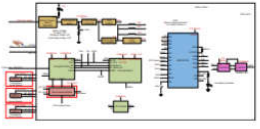
TIDA-0161
AFE4403
BQ24232
MSP432P4
ADS1292R
TMP117
TIDA-0100

lule (Software-
ection module
ker detection
UART interface
ble battery

- Pulse oximeter
- Electrocardiogram (ECG)

TI E2E™ Community — ASK Our E2E™ Experts

Comprehensive Design Guides



The following list provides details about the design:

- Supply Voltage = 5 V
- Charging current = 0.1 A
-
-
-
-
- 2)

Ho

-
-
- RISET = R99 = [870 AΩ / 0.1 A] = 8.7 kΩ

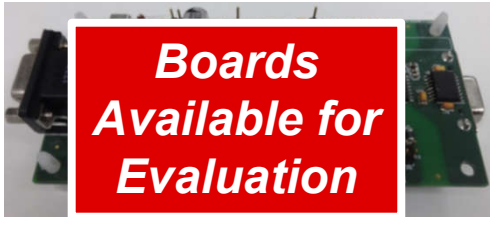
How the input current limit (ILIM) is set:

- RLIM = KILIM / I1-MAX
- KILIM = 1530 AΩ

Detailed Design Considerations & Applications Info

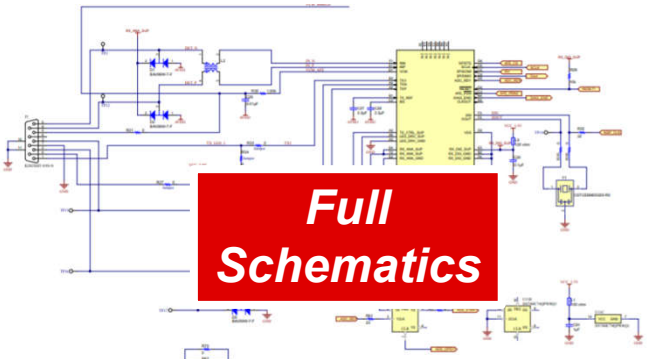
Designator	Quantity	Value	PartNumber	Manufacturer	Description	PackageReference
!PCB1	1		TIDA-01614	Any	Printed Circuit Board	
C1, C12, C14, C21, C29, C30, C32, C66, C67, C68, C70, C71	12	0.1uF	C1005X7R1E104M050BB	TDK	CAP, CERM, 0.1 µF, 25 V, +/- 20%, X7R, 0402	0402
C2, C3, C37, C47	4	10uF	GRM		R, 0603	0603
C4	1	1uF	C160		L, 0603	0603
C9	1	0.01uF	C603		C7R, 0603	0603
C10, C91	2	47uF	C121		RL, 1210	1210
C11, C13, C24, C25, C31, C86	6	1uF	GRM		R, 0402	0402
C15, C73	2	470pF	GRM		C0NP0, 0402	0402
C16	1	1500pF	GRM		X7R, 0402	0402
C17, C19, C63, C64, C83	5	0.1uF	C603		R, 0603	0603
C18, C20	2	2200pF	C120		7R, 0402	0402
C22	1	10uF	C260		5R, 0603	0603
C23, C72	2	2200pF	C0AT		X7R, AEC-Q200 Grade 1, 0402	0402
C26	1	0.01uF	C0K		C7R, AEC-Q200 Grade 1, 0402	0402
C27, C28	2	2.2uF	GRM		5R, 0603	0603
C33	1	68pF	GRM		2NP0, 0402	0402
C34	1	150pF	EEN		, 20%, 27 ohm, 8x10 SMD	8x10
C35	1	4.7uF	TPS		tm, SMD	6032-28
C36	1	10uF	CL21		5R, 0805	0805

Bill Of Materials

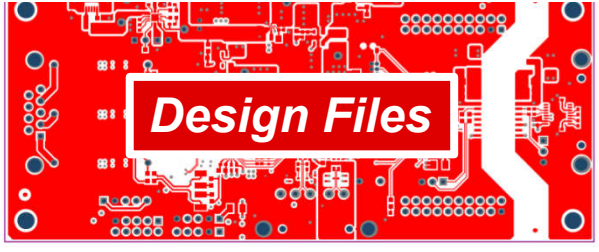


Boards Available for Evaluation

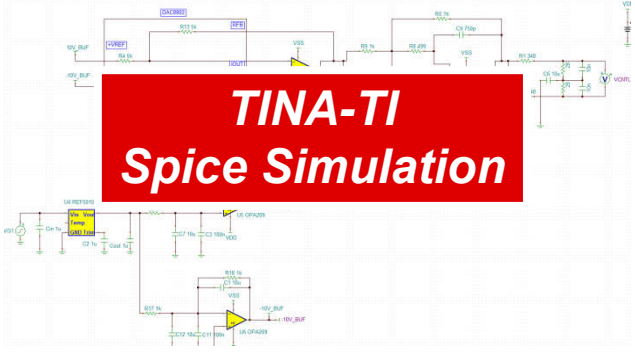
Comprehensive Test Results



Full Schematics



Design Files



TINA-TI Spice Simulation

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

Features

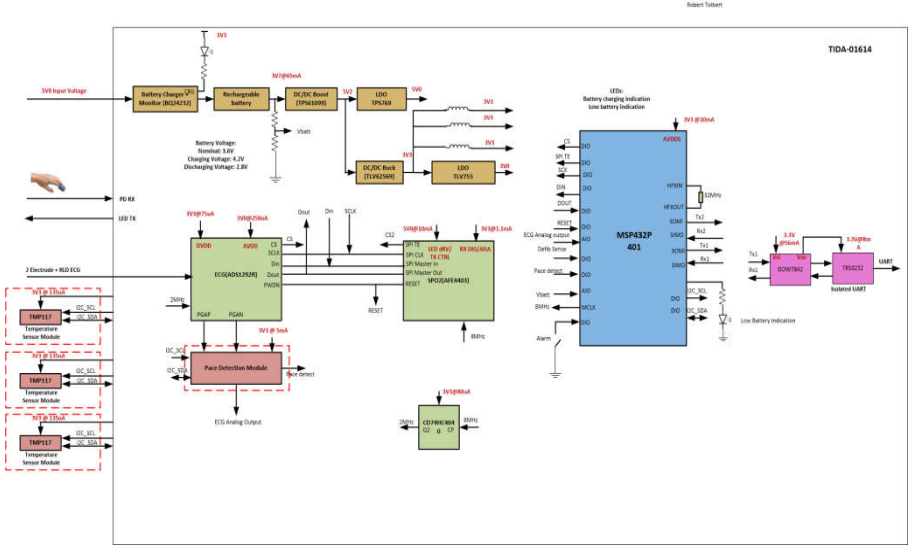
- System measures ECG, Heart Rate, SPO2, Respiration rate using ADS1292R and AFE4403 and Skin temperature using TMP117
- Circuit enables three electrode operation including right leg drive with good CMRR
- Pace detection circuit indicates presence of pacemaker
- Supports three 0.1 Celsius accurate sensors (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

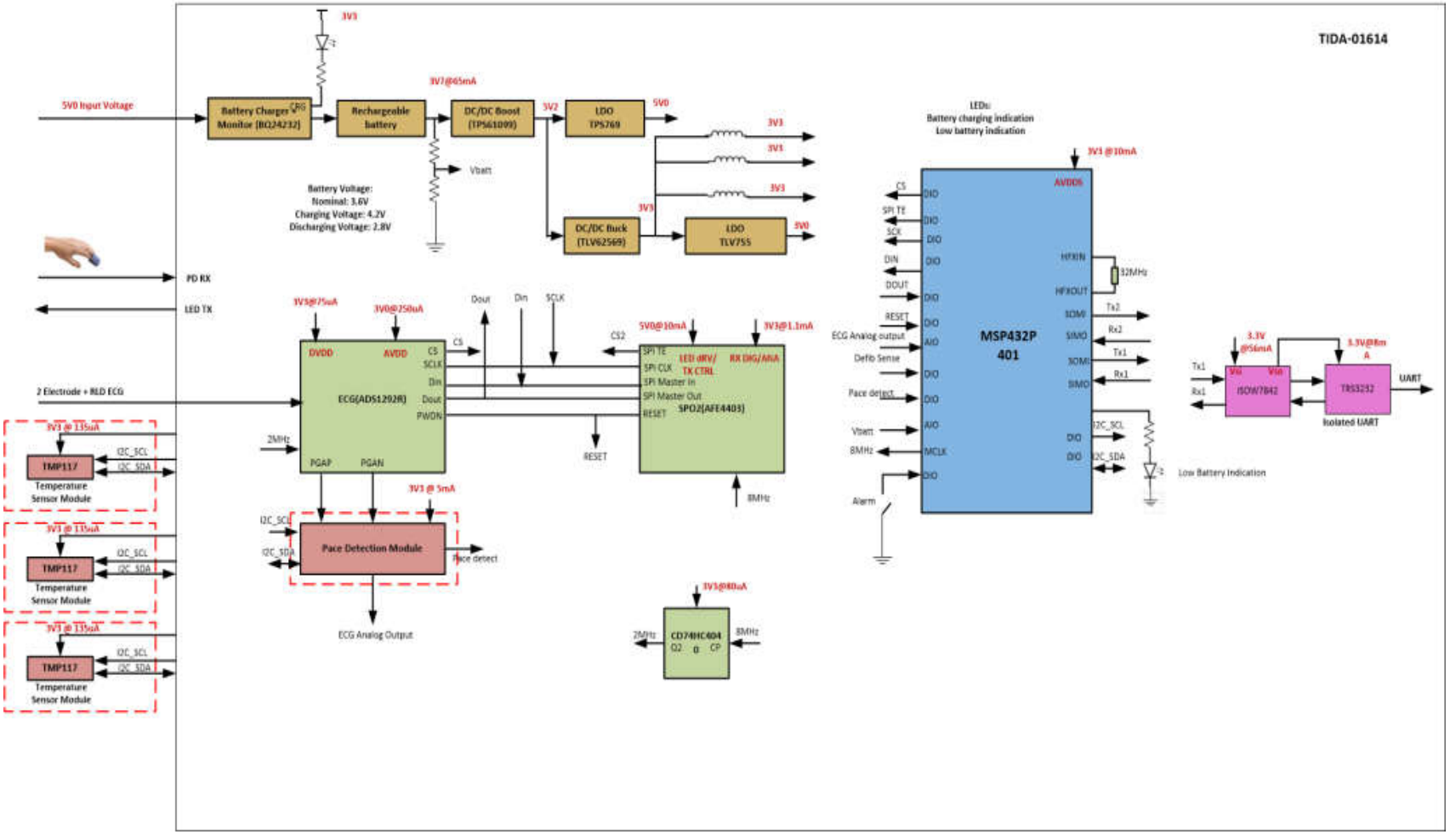
Applications

- Multiparameter Patient Monitor
- Medical Sensor Patches
- Pulse Oximeter
- Electrocardiogram (ECG)

Benefits

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




TIDA-01614
5V0 Input Voltage
Battery Charger & Monitor (BQ24232)
CHG
Rechargeable battery
3V7@65mA
DC/DC Boost (TPS61099)
3V2
LDO TPS769
5V0
3V1
3V1
3V3
Vbatt
Battery Voltage:
Nominal: 3.6V
Charging Voltage: 4.2V
Discharging Voltage: 2.8V
DC/DC Buck (TLV62569)
3V3
LDO TLV755
5V0
LEDs:
Battery charging indication
Low battery indication
3V1 @10mA
AVDD6
MSP432P 401
32MHz
HFXIN
HFXOUT
3DMI
3MO
3MI
3DMO
CS
SPI TE
SCK
DIN
DOUT
RESET
ECG Analog output
Defib Sense
Pace detect
Vbatt
8MHz
Alarm
I2C_SCL
I2C_SDA
Low Battery Indication
Tx2
Rx2
Tx1
Rx1
3.3V @56mA
3.3V@8mA
Vin
Vio
ISOW7842
TRS3232
UART
Isolated UART
PD RX
LED TX
2 Electrode + RLD ECG
3V3@75uA
3V0@250uA
DVDD
AVDD
CS
SCLK
Din
Dout
PWDN
ECG(ADS1292R)
PGAP
PGAN
2MHz
Dout
Din
SCLK
CS1
CS2
RESET
5V0@10mA
3V3@1.1mA
SPI TE
SPI CLK
SPI Master In
SPI Master Out
RESET
LED1 dRV/ TX CTRL
RX DIG/AMA
SPO2(AFE4403)
8MHz
3V3 @ 135uA
TMP117
I2C_SCL
I2C_SDA
Temperature Sensor Module
3V3 @ 135uA
TMP117
I2C_SCL
I2C_SDA
Temperature Sensor Module
3V3 @ 135uA
TMP117
I2C_SCL
I2C_SDA
Temperature Sensor Module
3V3 @ 5mA
I2C_SCL
I2C_SDA
Pace Detection Module
Pace detect
ECG Analog Output
3V3@80uA
2MHz
CD74HC404
Q2
Q
CP
8MHz

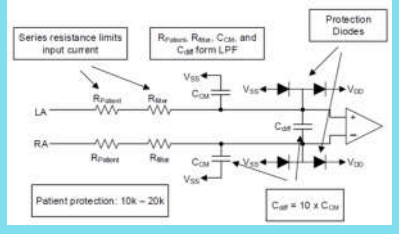
Design Challenges TIDA-01614 Solves

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

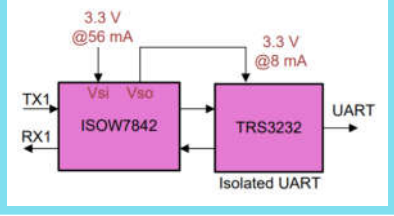
- Monitoring of ECG, Heart Rate, SPO2, PTT, Respiration rate and Skin temperature
- Single Lead ECG with RLD (ADS1292R)
  > Signal amplitude: 0.2mV~2mV (p-p);
  > BW0.05 Hz to 2000 Hz
- Supports 3 LED and 3 Photodiodes with ambient subtraction for SPO2 and Heart Rate monitoring with AFE4403
- Supports 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

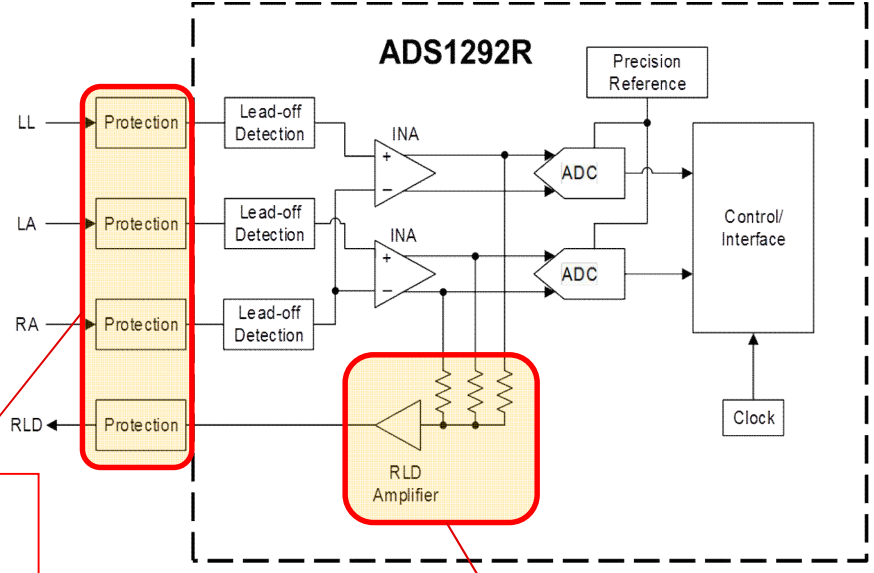


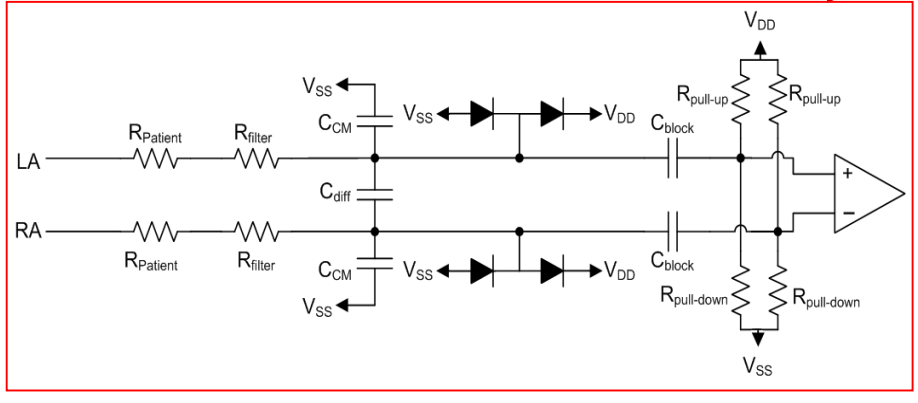
ECG Analog Front End

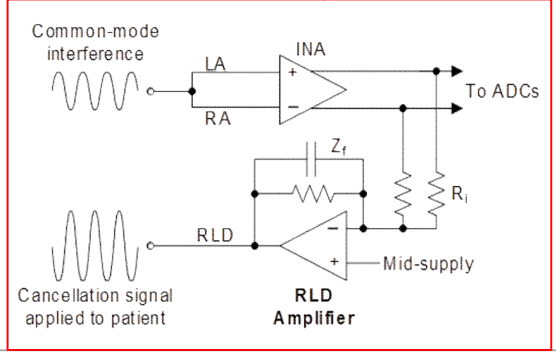
TIDA-01614: Multiparameter front-end reference design for vital signs patient monitor

Important Parameters:

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



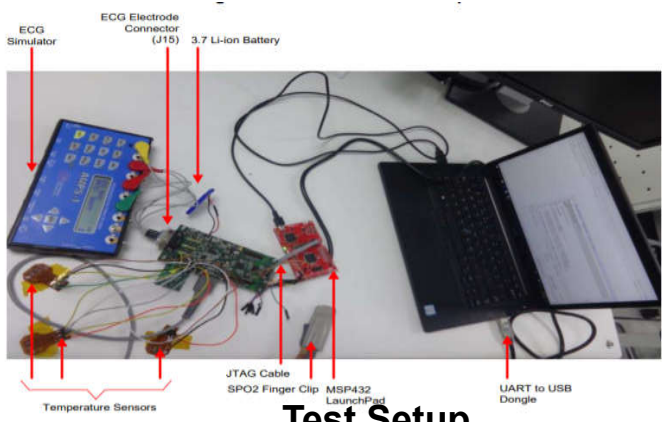




TIDA-01614 Test Setup and Test Results

Design Specs

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



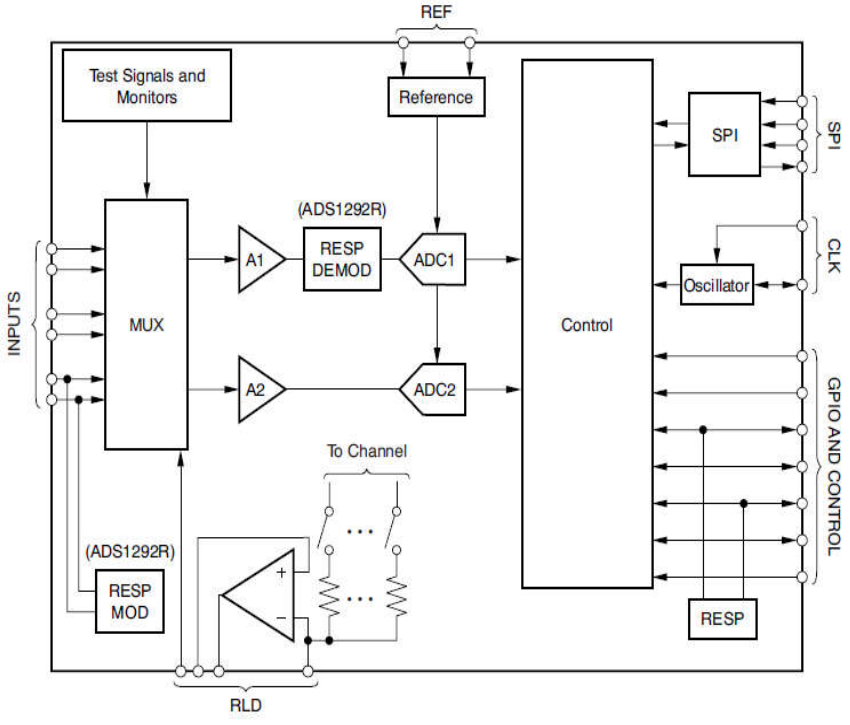
Test Setup

GUI Display

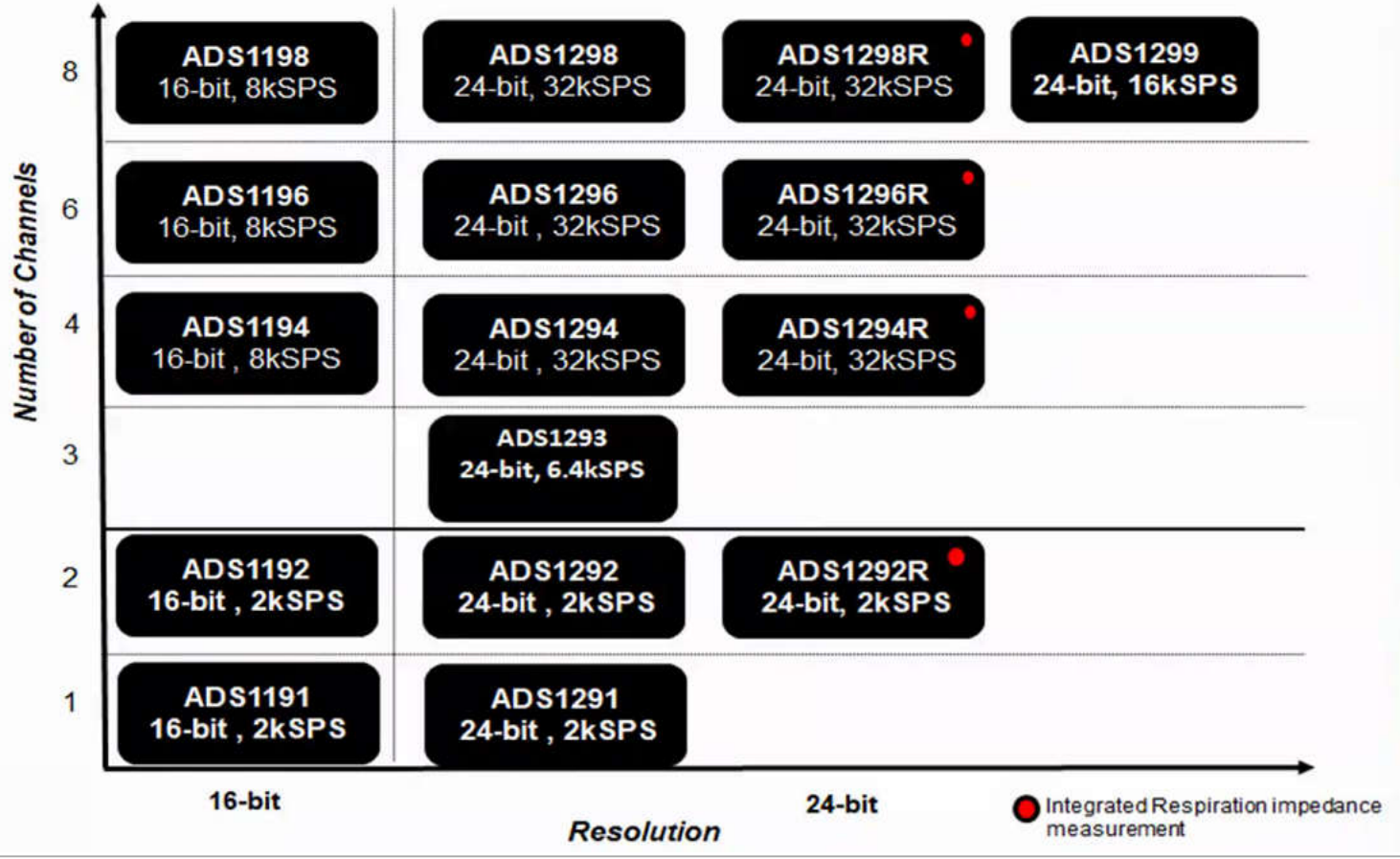
ADS1291/2

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



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

Applications

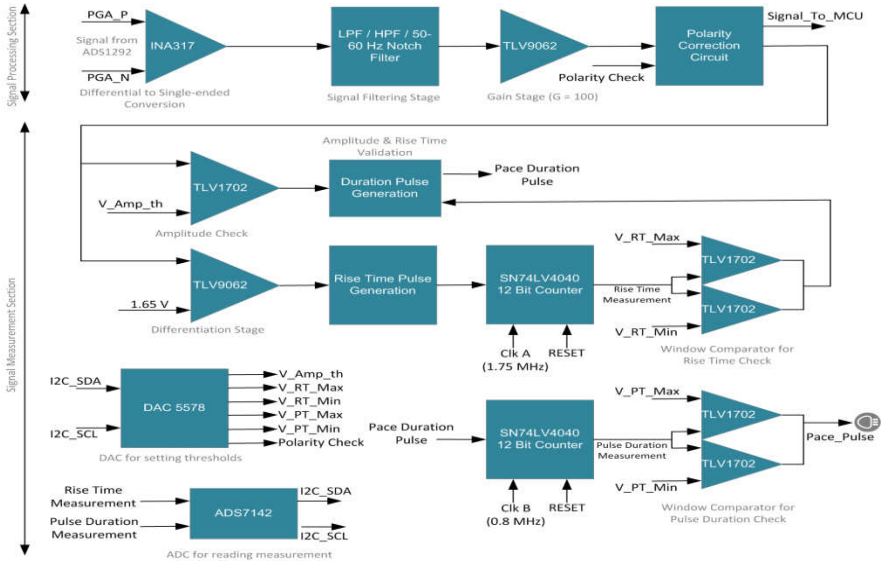
- Multi-parameter Patient Monitor
- Medical Sensor Patches
- Electrocardiogram (ECG)

Tools & Resources

- TIDA-010005 and Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software.
- Device Datasheets:
  - INA317
  - TLV9062
  - TLV1702
  - DAC5578
  - ADS7142

Benefits

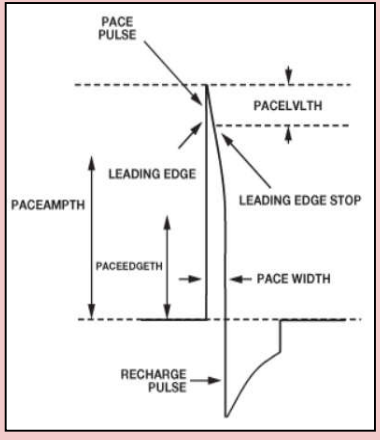
- Detection of various types of pacemaker pulse provides the user one stop solution
- Modular approach compatible with other patient monitoring TI Designs such as TIDA-01614
- Compact form factor
- A flag signal and onboard LED are the indication of presence of 'valid' pace signal.

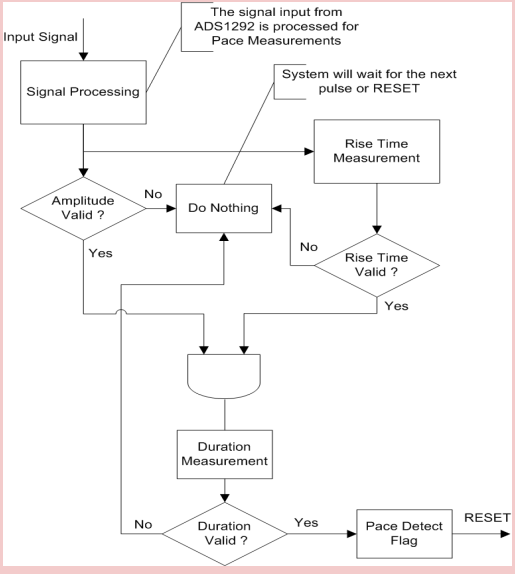


Design Challenges TIDA-010005 Solves

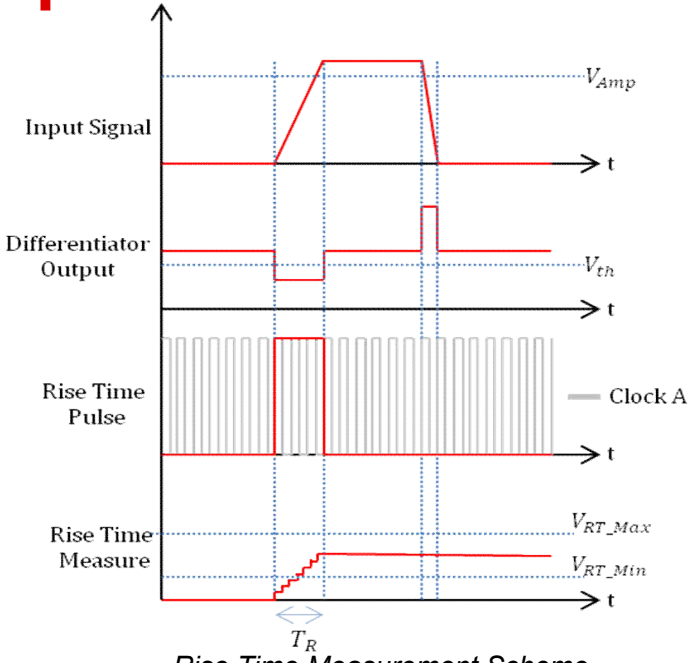
Design Challenge: Low noise, highly integrated signal path for ECG with lead-off and pace detection: to detect amplitude, rise time, width and polarity for diagnostics with different makes of Pacemaker

- 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

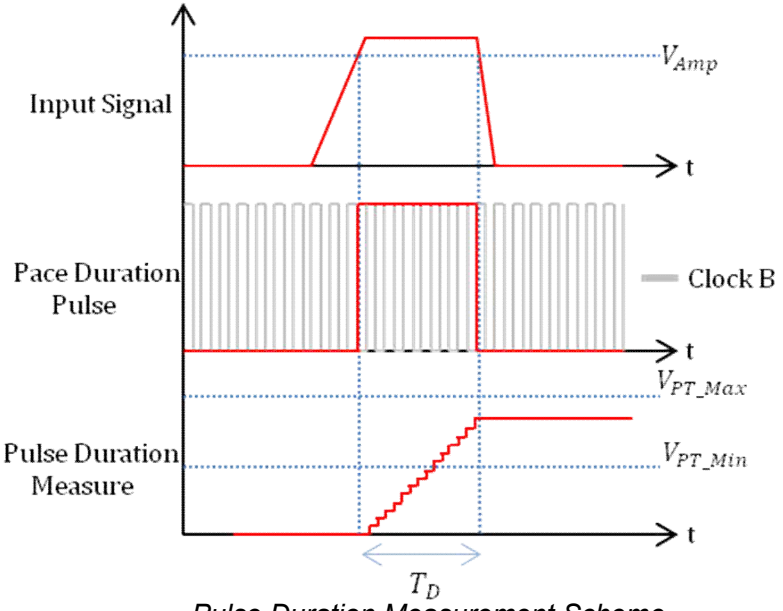




Proposed Solution



Rise Time Measurement Scheme



Pulse Duration Measurement Scheme

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:

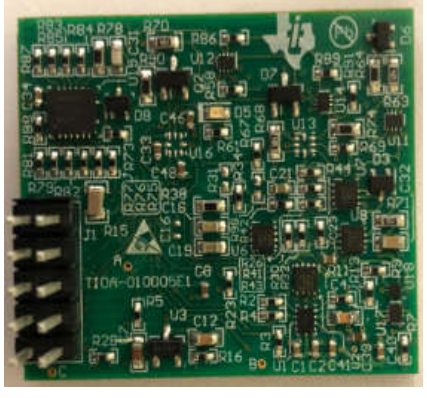
- *Amplitude* > V_{Amp_th}
- V_{RT_min} < *Rise Time Measure* (V_{RT}) < V_{RT_max}
- V_{PT_min} < *Pulse Duration Measure* (V_{PT}) < V_{PT_max}

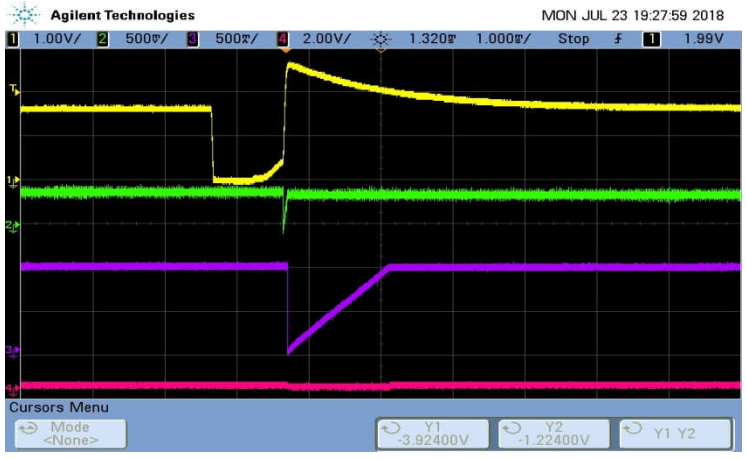
V_{Amp_th}, V_{RT_min}, V_{RT_max}, V_{PT_min} *and* V_{PT_max} *comes from the DAC*

TIDA-010005 Technical Details

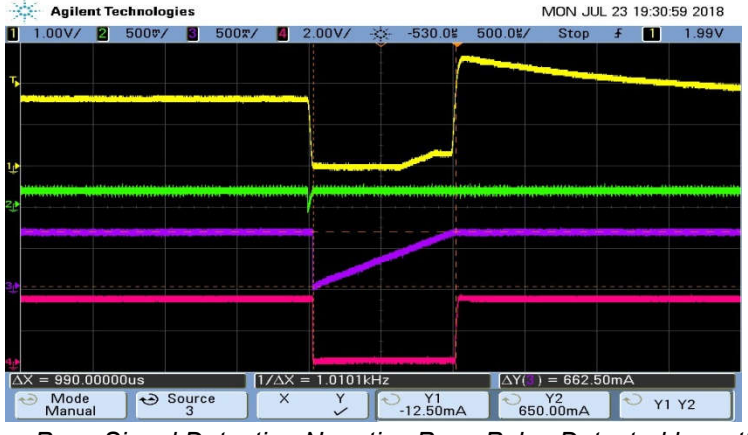
Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Input Voltage	3.3 V	Supply voltage to the system
PGAP	Analog non-inverting ECG input to system	Analog output of ADS129X PGA non-inverting pin which serves as input to the TIDA-010005
PGAN	Analog inverting ECG input to system	Analog output of ADS129X PGA inverting pin which serves as input to the TIDA-010005
Rise-time (T_R) measurement range	30–200 µs	The measurement range of the rise time of the pace pulse
Pace pulse duration (T_D) measurement range	0.1–2 ms	The measurement range of the duration of the pace pulse
Input *Pace* signal amplitude range	8 mV – 700 mV	The range of amplitude of the pace signal tested with the TIDA-010005
Average steady-state current consumption	8 mA	Current consumption of the system
Clock A frequency	1.75 MHz	Onboard clock to the counter for T_R measurement
Clock B frequency	806 kHz	Onboard clock to the counter for T_D measurement
ADC resolution	12 bits (2 channel)	ADS7142 ADC to capture the rise time and duration
DAC resolution and channels	8 bits (8 channel)	DAC5578 sets the various threshold for pace pulse. I²C enabled





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

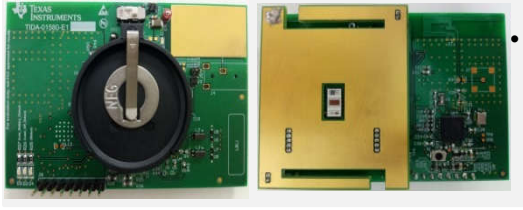
Features

- Simple Wearable Multi-Parameter Patient Monitor for Photo-plethysmography (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

Target Applications

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

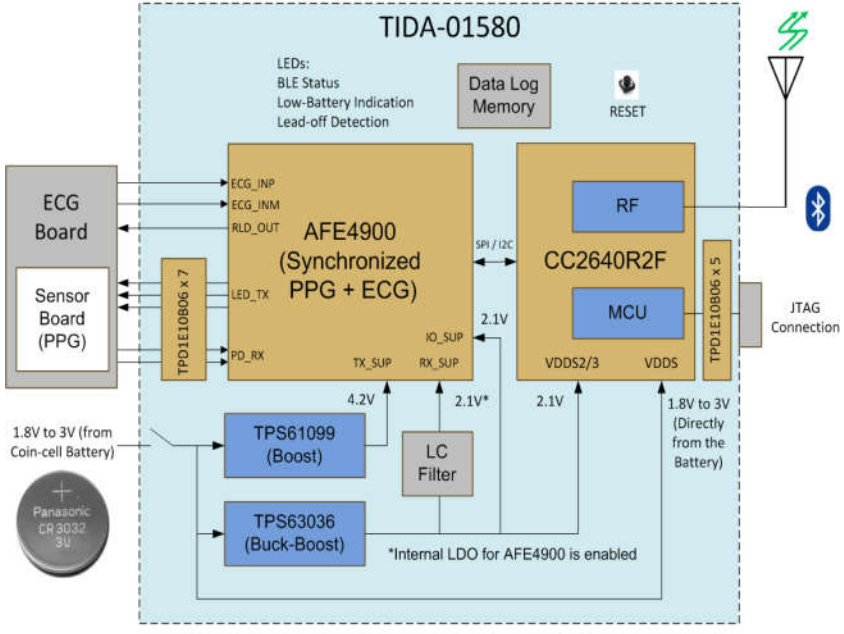
Tools & Resources



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

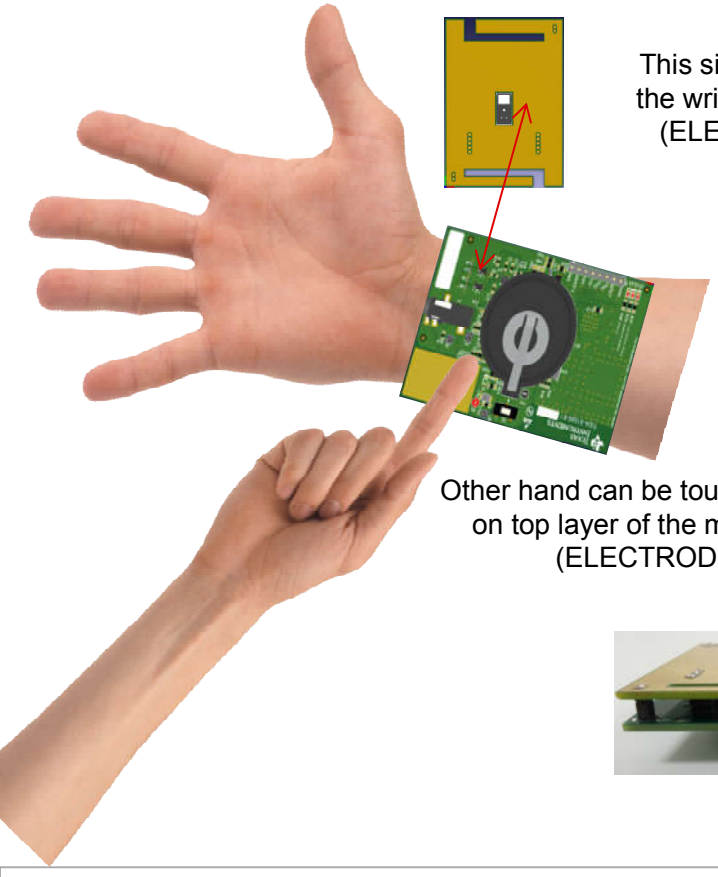
Benefits

- 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



TIDA-01580 Medical Patches

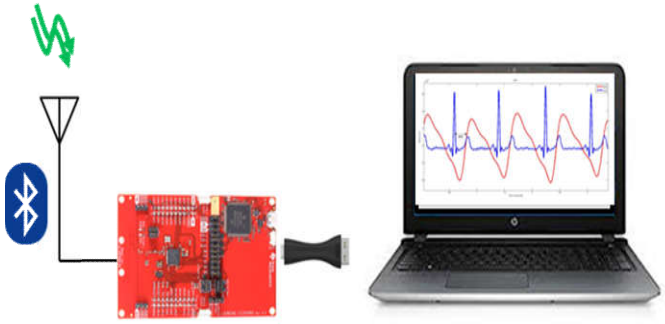
This board is connected on bottom of the main board



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



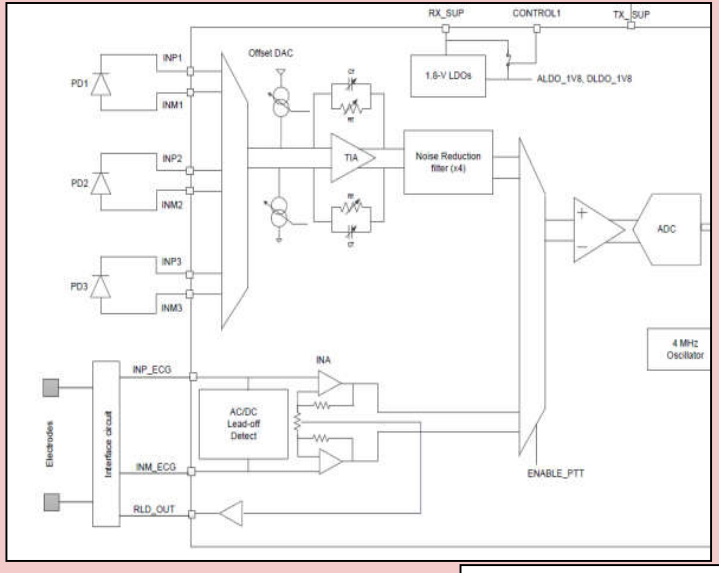
LAUNCHXL-CC2640R2

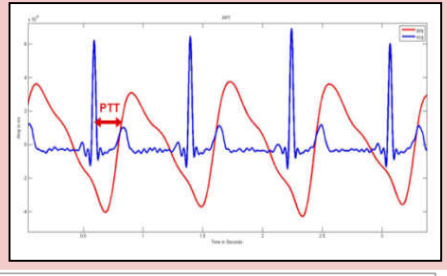
- LAUNCHXL-CC2640R2F receives the signals remotely and displays on LabView GUI
- The design uses BLE 5.0 with an advertising time = 100ms

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)

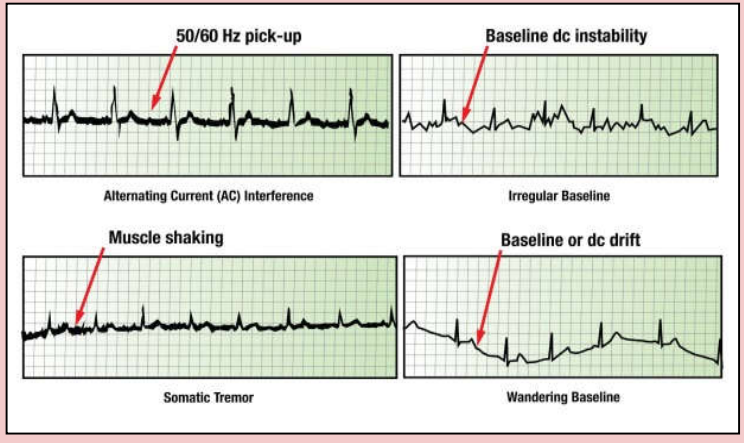


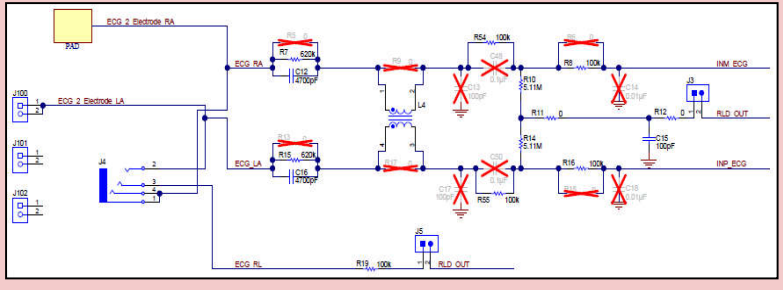


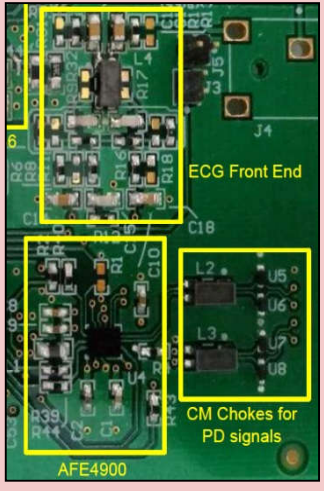
Design Challenges TIDA-01580 Solves

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



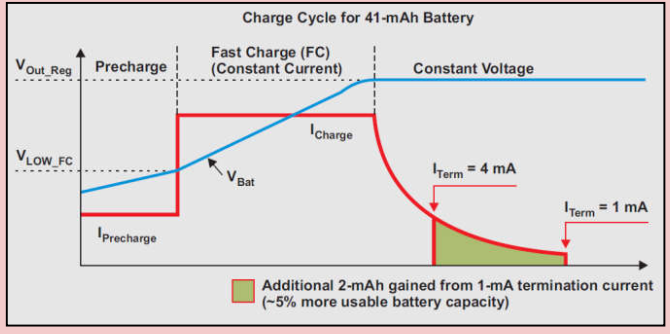


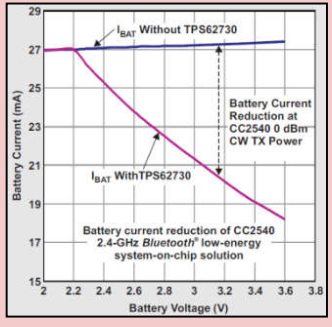


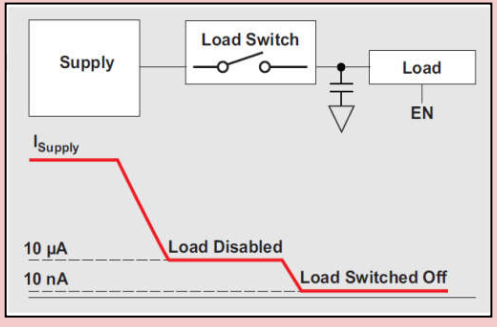
Design Challenges TIDA-01580 Solves

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!)







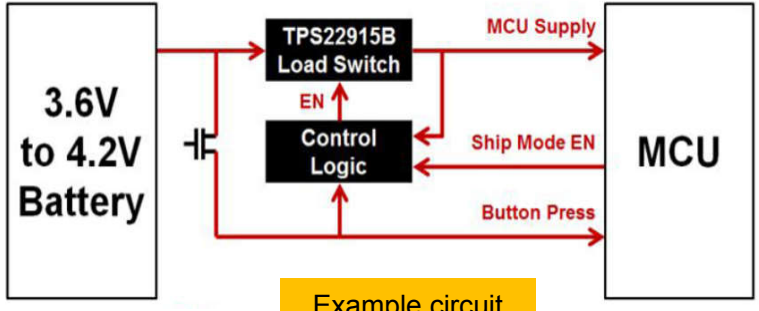
SHIP mode

- 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.

SHIP mode

Out of 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)



Example circuit using load switch

Low-voltage switchers

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

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

	TPS61022	TPS61099	TPS61291	LMR61428
Vin (Min) (V)	0.5	0.7	0.9	1.2
Vin (Max) (V)	5.5	5.5	5	14
Vout (Min) (V)	2.2	1.8	2.5	1.24
Vout (Max) (V)	5.5	5.5	3.3	14
Switch current limit (Typ) (A)	8	1	1	2.85
Regulated outputs (#)	1	1	1	1
Switching frequency (Min) (kHz)		1000	2300	300
Switching frequency (Max) (kHz)	1000	3000	2300	2000
Iq (Typ) (mA)	0.027	0.0008	0.005	0.1
Features	Enable Light Load Efficiency Load Disconnect Pre-Bias Start-Up Synchronous Rectification UVLO Fixed	Synchronous Rectification	Bypass Mode	Enable
Duty cycle (Max) (%)	97	90	90	70

Full system | Multi-parameter patient monitor + wireless sensors

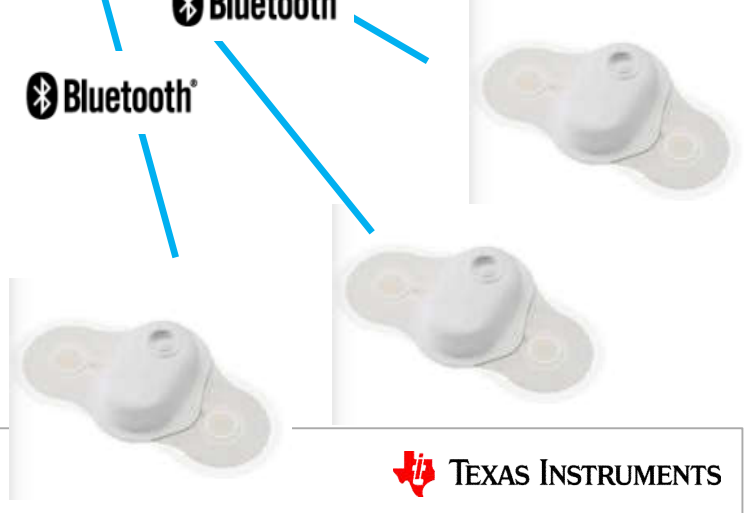
Nurse's Station /
Doctor's Office

Wi Fi CERTIFIED

Bluetooth

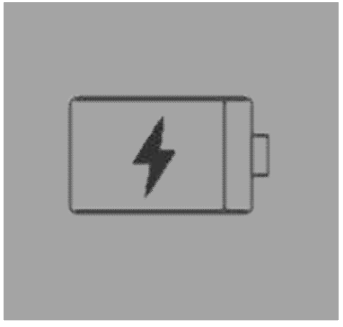
Bluetooth

Bluetooth



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

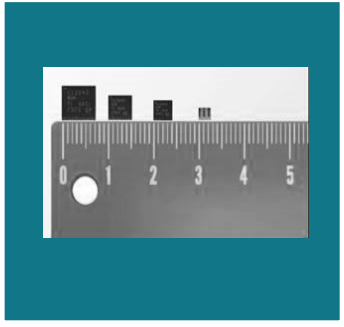
Ease of use

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

Secure

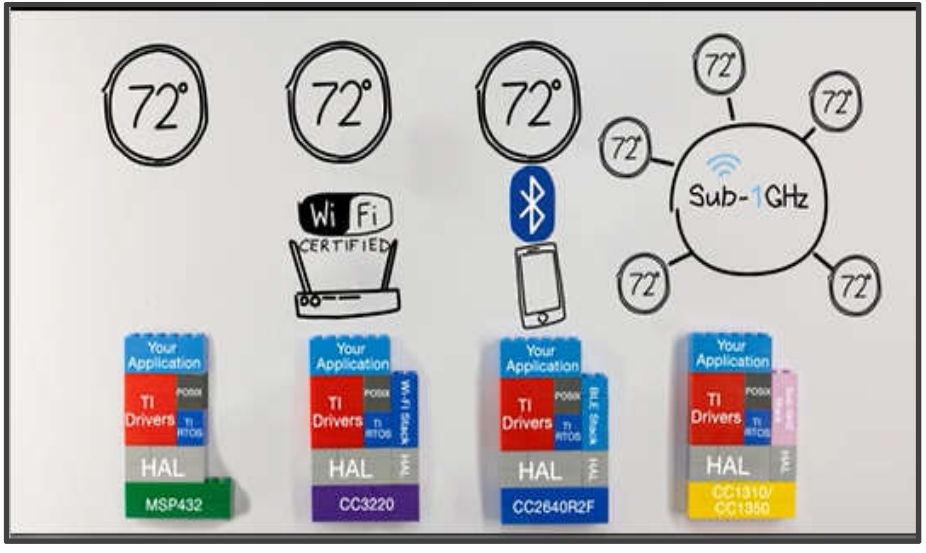
- FIPS 140-Level 1 validation
- Offload CPU bandwidth – HW crypto accelerators
- Secure boot

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

100% code reuse

Bluetooth

Full-featured Bluetooth 5 solutions

Features all mode Bluetooth 5 certified support, automotive-qualified wireless MCUs, and has the industry's smallest full-featured Bluetooth 5 solution.

BLE overview

View our BLE products

Sub-1GHz

Ultra-low power long-range star network

Out-of-box star network solution, multi-year operation on coin cell battery. Programmable ultra-low power sensor controller interface.

Sub-1GHz overview

View our Sub-1GHz product

Wi Fi CERTIFIED

Dual-core and low power SoCs

FIPS-verified ICs optimized for low power. Enhanced application and network security capabilities.

Wi-Fi overview

View our Wi-Fi products

zigbee

Certified mesh network

Zigbee 3.0-certified with lowest power integrated +20dBm PA and green power support.

Zigbee overview

View our Zigbee products

THREAD

Self-healing low-power mesh network

Lowest power thread platform. OpenThread stack support. Optimized router examples available in SimpleLink academy.

Thread overview

View our Thread products

Multi-standard

Concurrent wireless protocol operation

Concurrent multi-protocol & multi-band. BLE + Zigbee or BLE + Sub-1 GHz. Pre-built multi-protocol manager with flexible priority scheduler.

Multi-standard overview

Multi-standard products

SDK

Common software

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

Applications

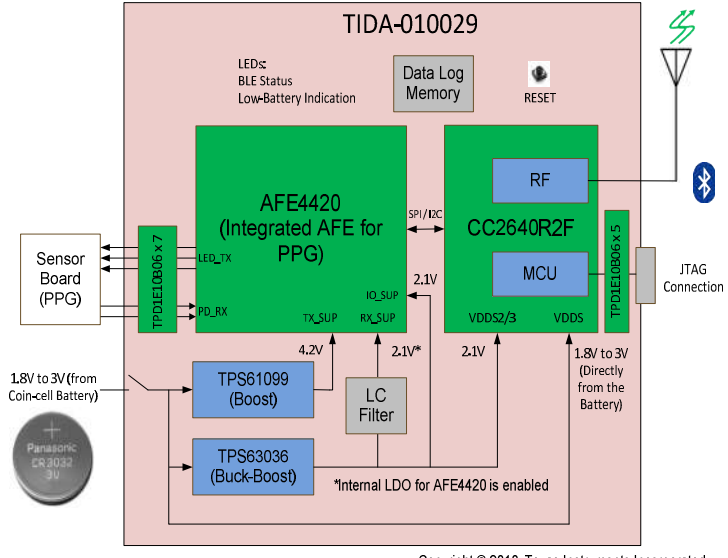
- Pulse Oximeter
- Wearable Fitness and Activity Monitor
- Multiparameter Patient Monitor
- Medical Sensor Patches

Tools & Resources

- **TIDA-010029 and/or Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, etc.
- **Device Datasheets:**
  - AFE4420
  - CC2640R2F
  - TPS63036
  - TPS61099
  - TPD1E10B06

Benefits

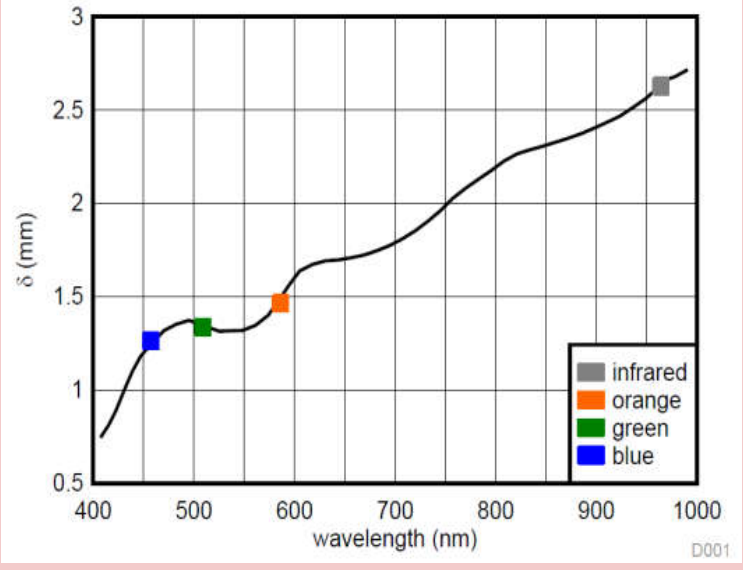
- PPG supports 4 LEDs and 4 PDs with Automatic Ambient subtraction to improve the SNR
- Continuous Monitoring with lower operating power ensures battery life of 100 hours for continuous operation
- Flexibility of ultra low power modes and integrated FIFO can keep MCU into sleep to increase the battery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



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 the 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)

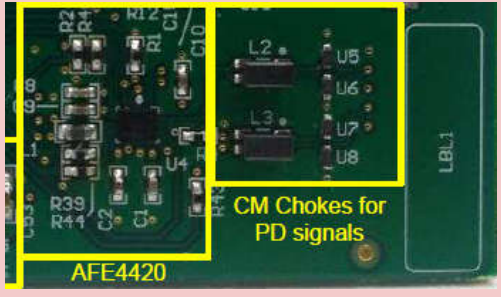


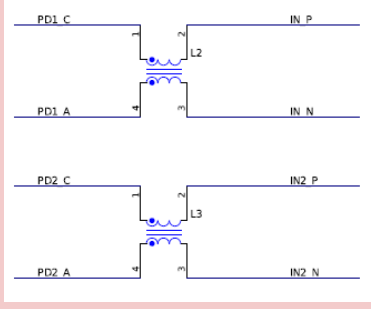
Source: An applicable approach for extracting human heart rate and oxygen saturation during physical movements using a multi-wavelength illumination optoelectronic sensor system (Link)

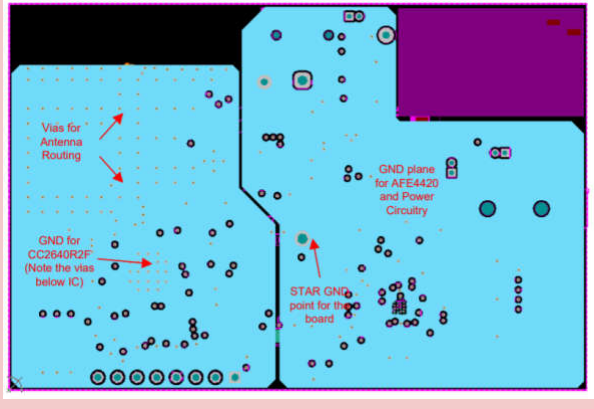
Design Challenges TIDA-010029 Solves

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

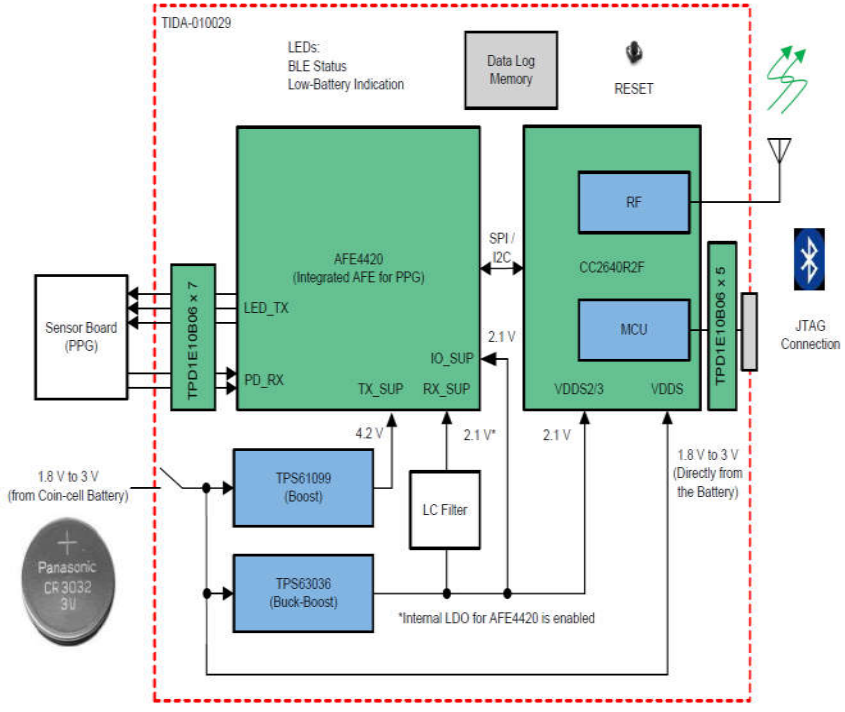
- Supports wireless data transfer through Bluetooth® low energy 4.2 and 5.0 with CC2642R
- CM chokes placed at the PD inputs to reduce noise effects on very sensitive signals coming from photo diodes
- Layout Optimization for AFE and BLE to minimize interface while maintain the measurement accuracy
- 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

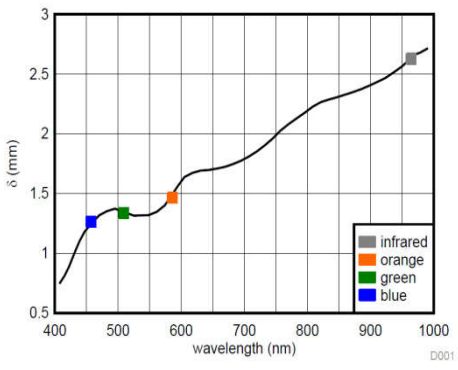


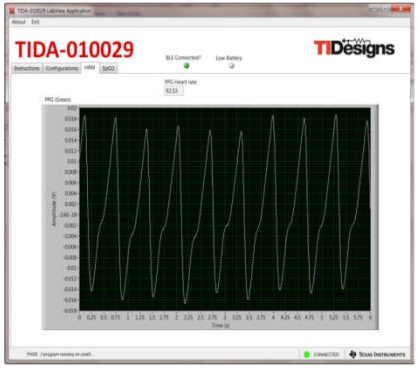




TIDA-010029 board details







TIDA-010043: Efficient, high-current, linear LED driver reference design for SpO2 and other medical applications

Features

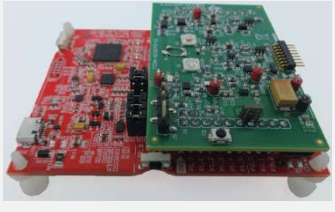
- Higher efficiency by providing headroom control to optimally drive LED
- Diagnostics (LED open, LED short, LED disconnect) and protection mechanism for fault by disconnecting the supply using e-fuse
- Wide operating input range from 1.8 V to 5.5 V to support all battery type inputs
- Programmable range 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)

Target Applications

Pulse oximeter

Multiparameter patient monitor

Tools & Resources

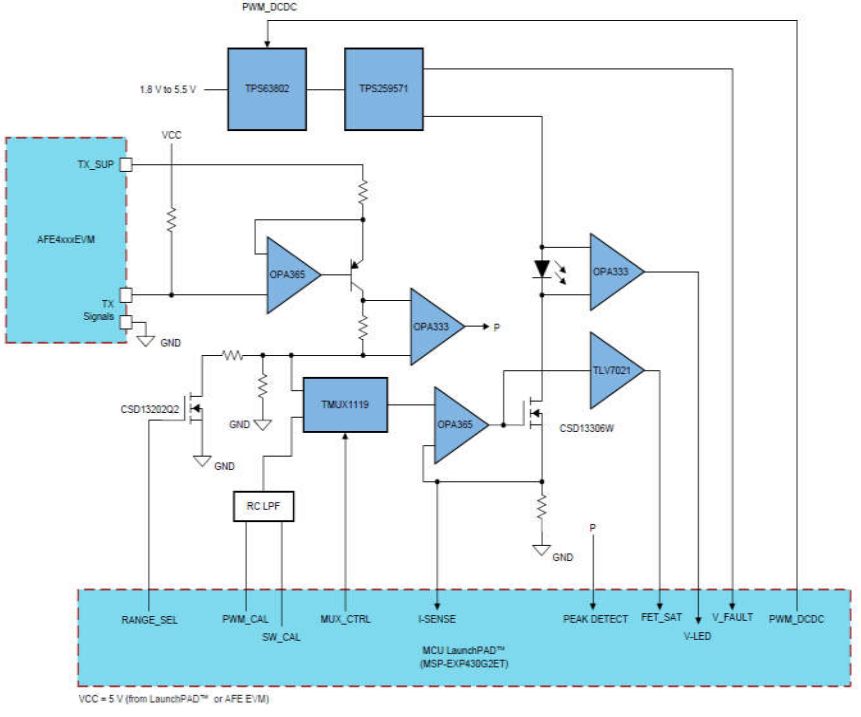


Device datasheets:

- TPS63802
- TPS2595
- CSD13306W
- CSD13202Q2
- TMUX1119
- TLV7021
- OPA333
- OPA365

Benefits

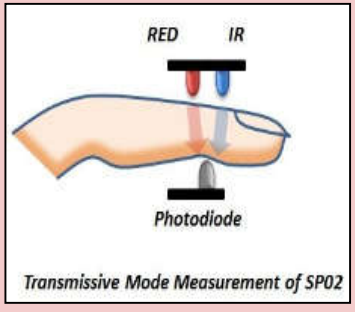
- Built-in self-calibration and look-up table for headroom control
- Dynamic adjustment of the LED supply voltage, to achieve optimal efficiency at the programmed current levels

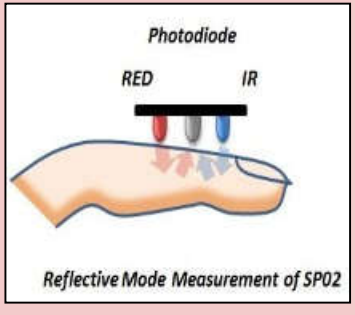


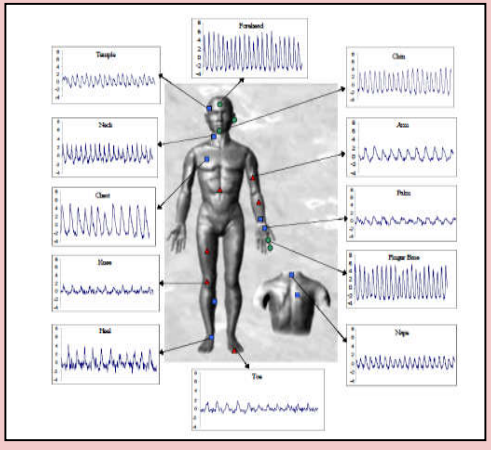
Design Challenges TIDA-010043 solves

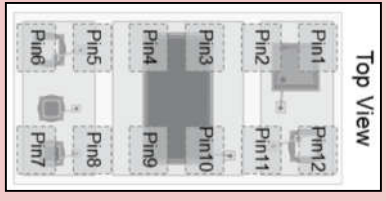
Design Challenge: Accurate SpO2 measurement across varying photodiode placements, wavelengths and body physiologies through optimizing LED driving circuit and photo-diode signal chain at low power

- 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)

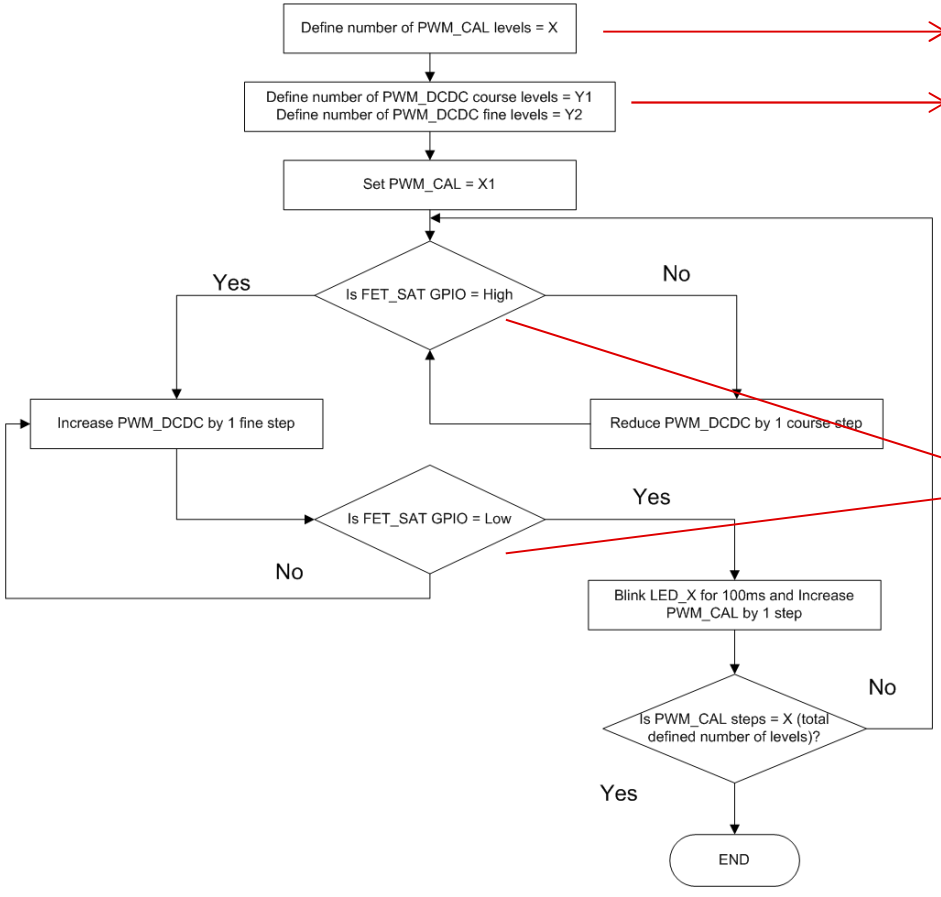








TIDA-010043 Technical Details – flowchart

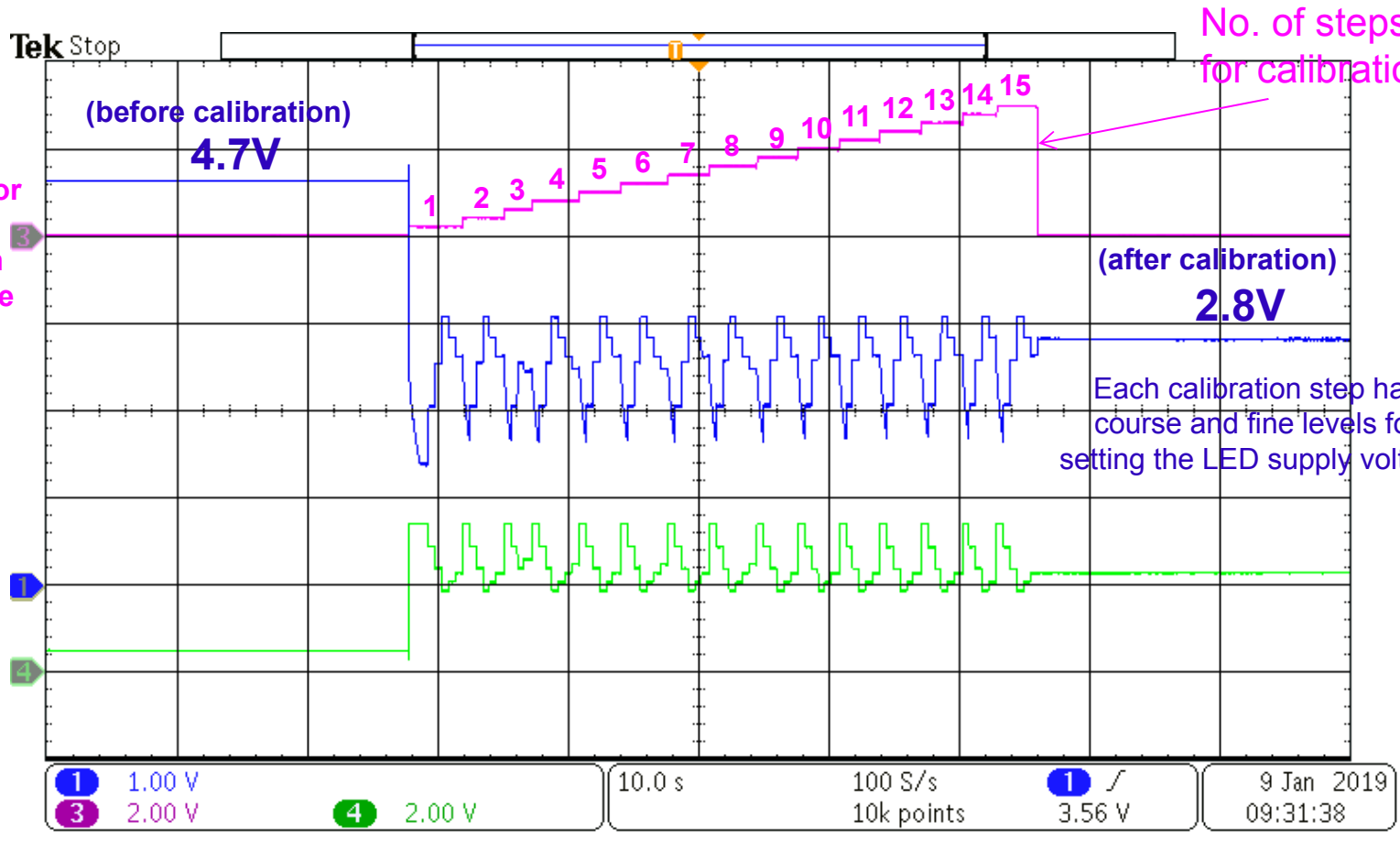


These are number of steps for calibration

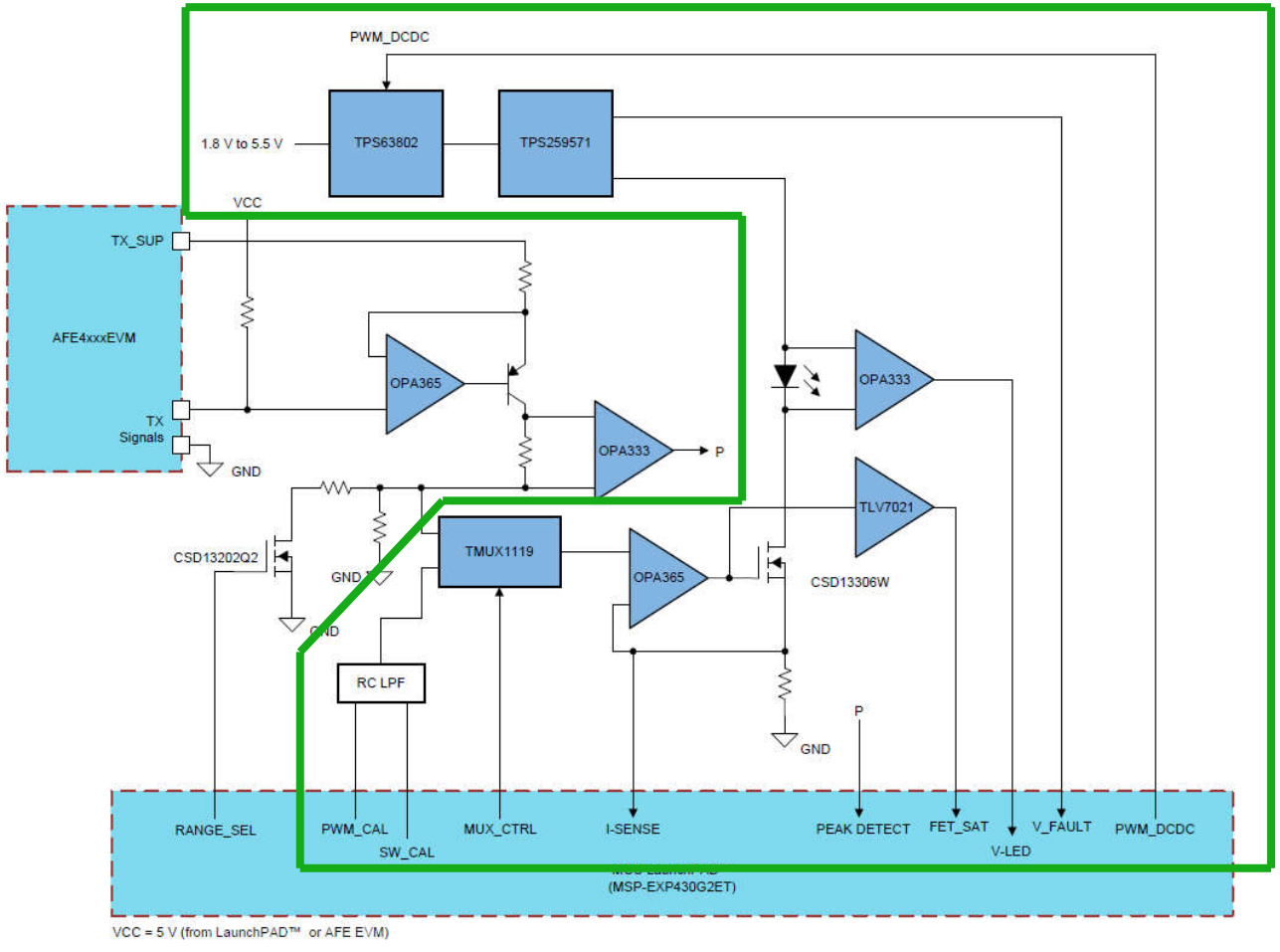
These are course and fine levels for setting the PWM to set the LED supply voltage (Each step in calibration has to go through course and fine level adjustment)

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

TIDA-010043 Technical Details – Calibration



TIDA-010043 Technical Details – block diagram



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

Applications

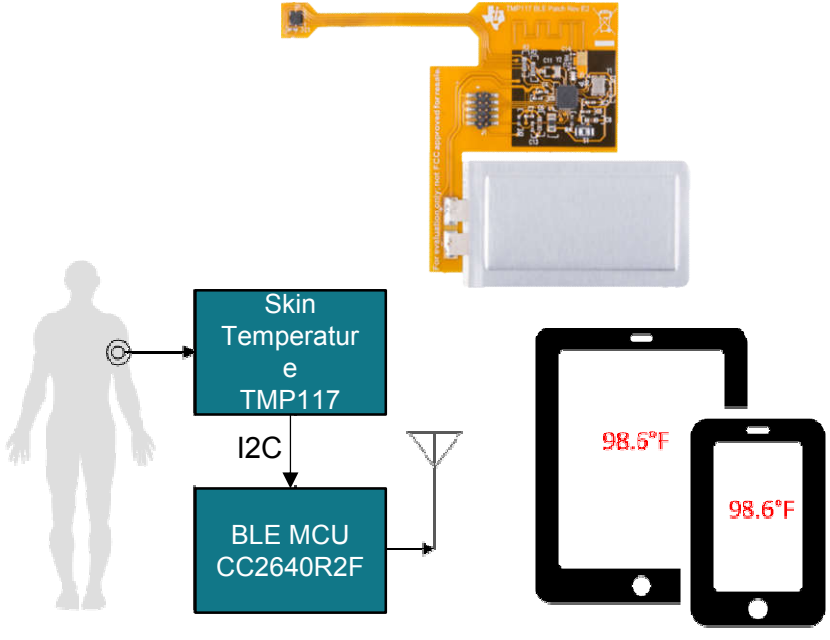
- Medical Sensor Patches
- Multiparameter Patient Monitors
- Smart Patches

Tools & Resources

- **TIDA-01624 and/or Tools Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, etc.
- **Device Datasheets:**
  - TMP117
  - CC2640R2F

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



TMP117x

Ultra-High Accuracy Digital Temp Sensor with integrated non-volatile memory

Features

Accuracy

TI Part	Accuracy (°C)	Accuracy Full Range
TMP117M	±0.1°C @ (30°C to 45°C)	±0.2°C @ (0°C to 85°C)
TMP117	±0.1°C @ (-20°C to 50°C)	±0.3°C @ (-55°C to 150°C)
TMP117N	±0.2°C @ (-40°C to 100°C)	±0.3°C @ (-55°C to 150°C)

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

Integrated EEPROM

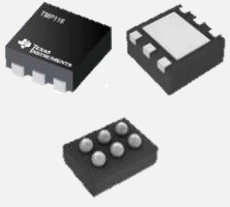
Low power consumption

- 140uA Iq during conversion
- 3.5uA 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

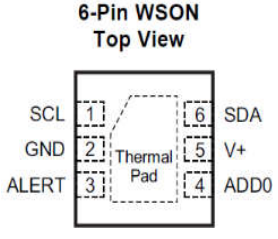
Low Power Consumption

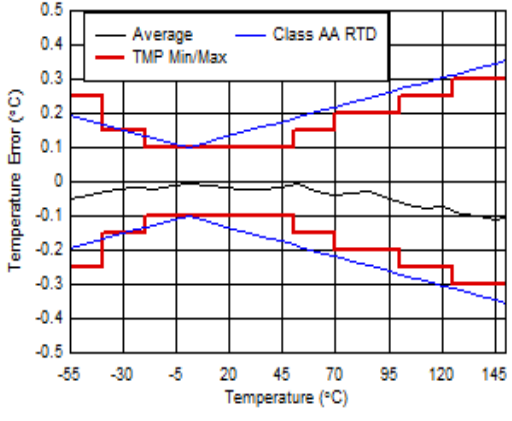
- 3.5uA Average Iq @ 1Hz; serial bus inactive
- 150nA Shutdown Iq; serial bus inactive

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

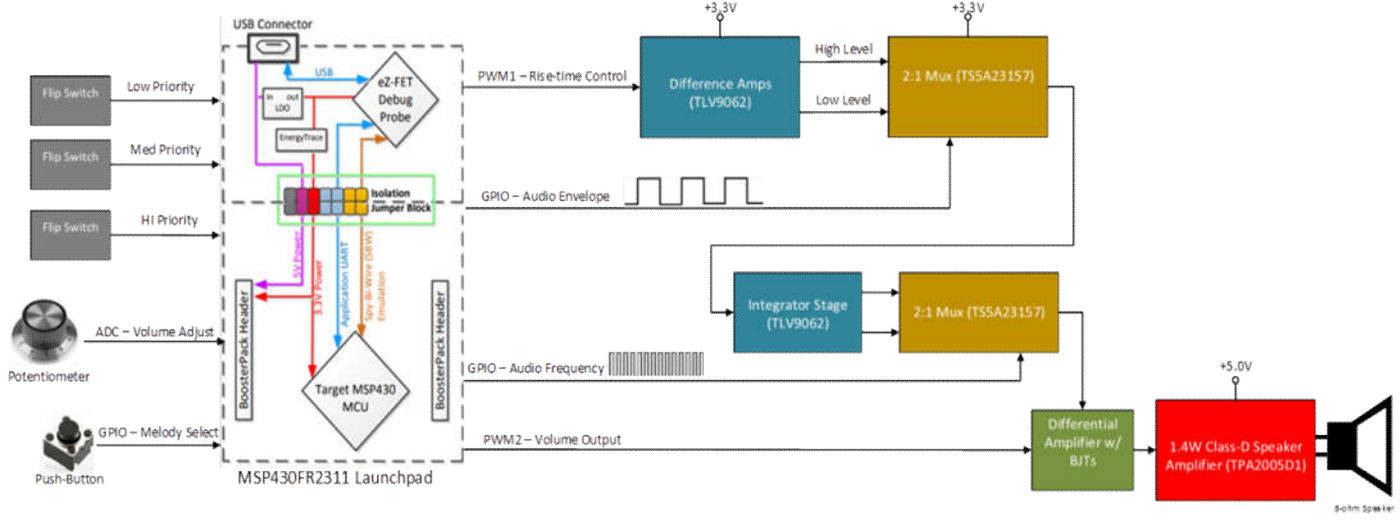
- Provides a solution that can be used for producing auditory alarms described in the IEC60601-1-8 medical specification.
- Capable of outputting low, medium, and high priority alarms with software-adjustable rise/fall time, pulse duration, pulse spacing, and burst spacing
- Can output 8 different alarm 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

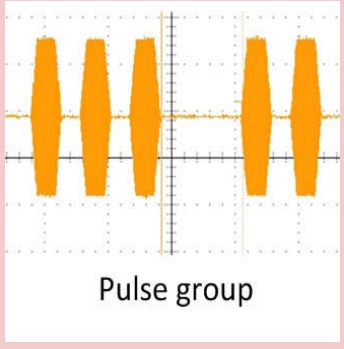


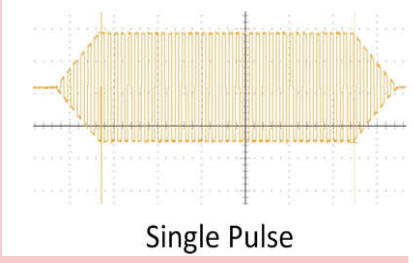
Key Design Challenge: Technical details

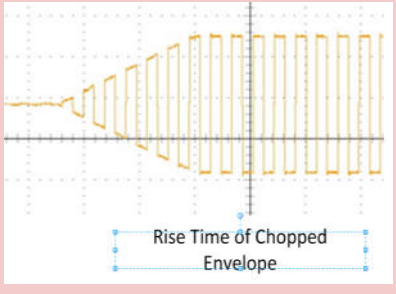
IEC60601-1-8 based medical alarm tone generation & coincidence detection

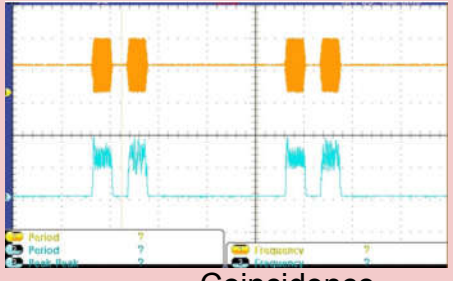
- Provides a solution that can be used for producing auditory alarms described in the IEC60601-1-8 medical specification.
- With a Low cost microcontroller and some external hardware, Analog Burst patterns are created. The Rise and Fall times, the Amplitude ,width and Frequency of these Bursts are all 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



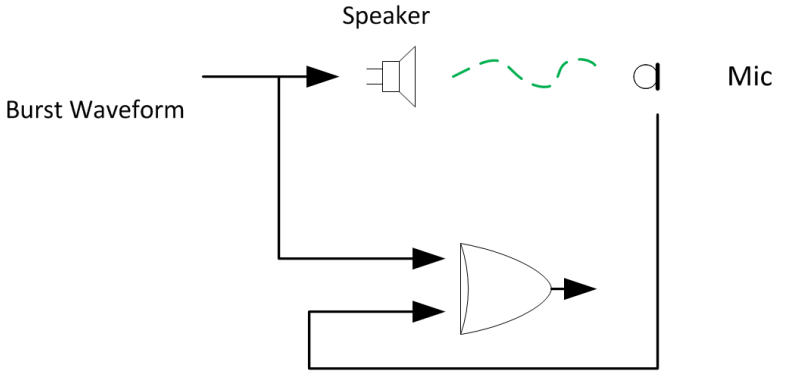




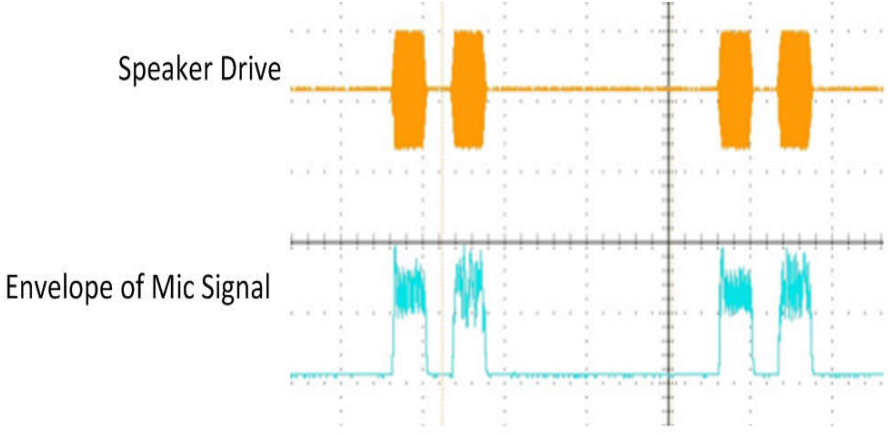


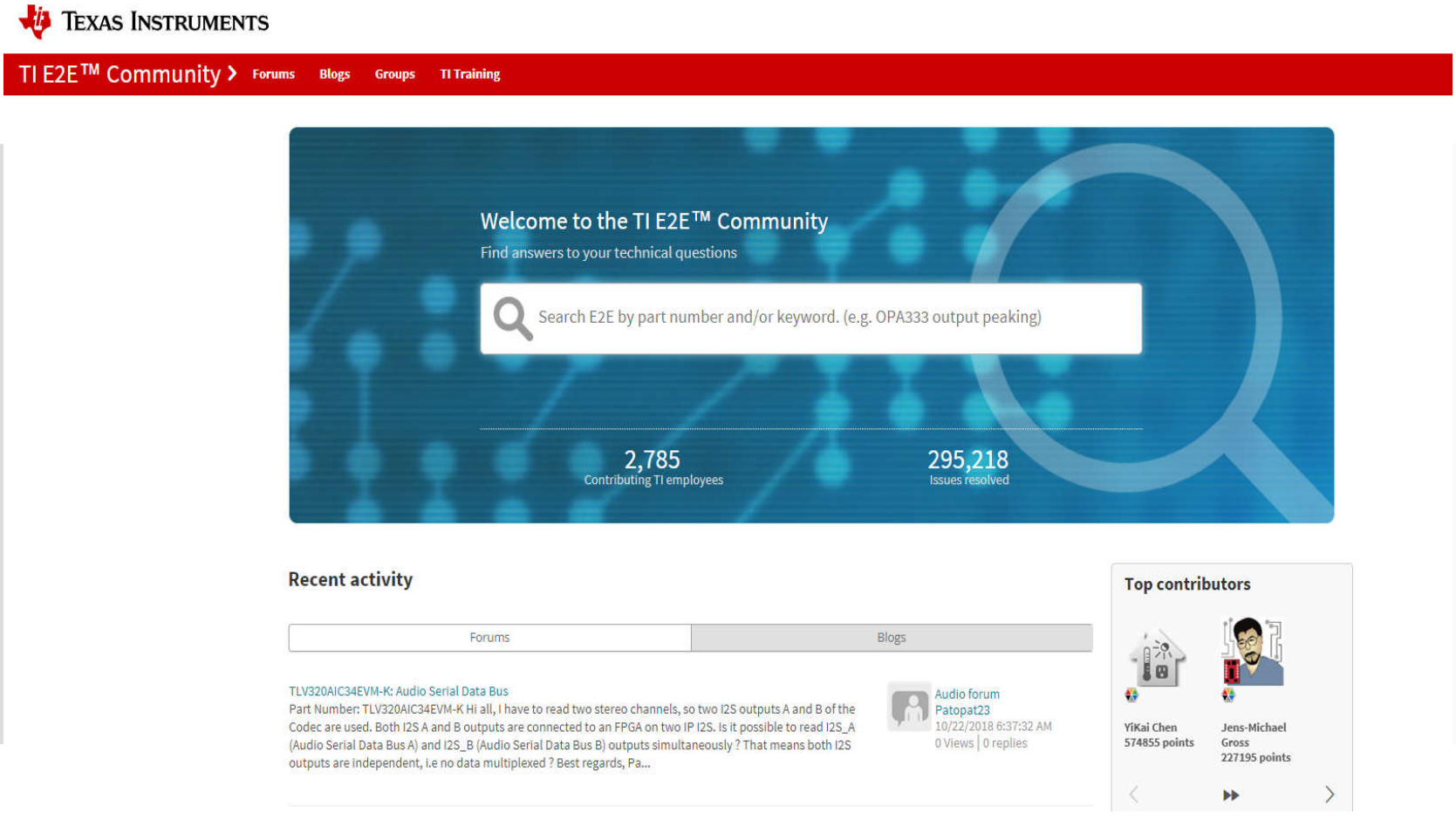
Coincidence Detection

TIDA-010040 – Coincidence Detection



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

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TLV320AIC34EVM-K: Audio Serial Data Bus
Part Number: TLV320AIC34EVM-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, i.e no data multiplexed ? Best regards, Pa...
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