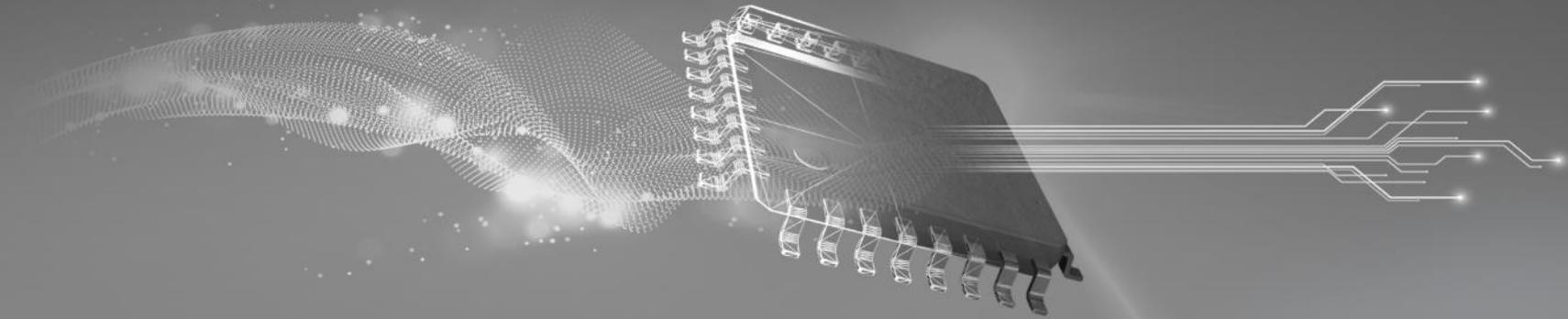


TI TECH DAYS



Design challenges of wearable healthcare and patient monitoring

Kelvin Le

SEM – Medical

Agenda



TI in medical



Market trends



Fundamentals and challenges



Reference designs

TI semiconductors in every medical category



Medical imaging



Patient monitoring & diagnostics



Medical equipment



Home healthcare



Personal care & fitness



Medical sector page

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- MRI
- Ultrasound scanners
- X-ray systems

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- Clinical digital thermometer
- Digital stethoscope
- Electrocardiogram (ECG)
- Endoscopes
- Eye, ear, nose and throat exam
- In vitro diagnostics
- Medical sensor patches
- Mother and neonatal care monitors
- Multiparameter patient monitor
- Pulse oximeter
- Sleep diagnostics

Home healthcare

- Blood glucose monitors
- Blood pressure monitors
- CPAP machines
- Electronic thermometers
- Hearing aids
- Oxygen concentrator
- Telehealth systems

Medical equipment

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- Dialysis machines
- Electronic hospital bed & bed control
- Infusion pumps
- Medical accessories
- Medical chairs and tables
- Motorized electronic wheel chair
- Surgical equipment

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- Electric toothbrush
- Fitness machines
- Wearable fitness & activity monitor
- Beauty and grooming

Industrial >

- Automotive & enterprise computing
- Enterprise machine
- Enterprise projectors
- Medical**
- Motor drives
- Power delivery
- Pro audio, video & signage
- Test & measurement

Personal electronics >

- Connected peripherals & printers
- Data storage
- Gaming
- Home theater & entertainment
- Mobile phones
- PC & notebooks
- Portable electronics
- Tablets
- TV
- Wearables (non-medical)

Reference designs >

Find reference designs leveraging the best in TI technology – from analog and power management to embedded processors.

All designs include a schematic, test data and design files.

Internet of Things >

TIDA-01168

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.

[View more](#)

REFERENCE DESIGNS (11)

PRODUCTS (15)

port & training

Sensors (4)

Analog Temperature Sensors (1)

Digital Temperature Sensors (3)

TMP117 – $\pm 0.1^\circ\text{C}$ accurate digital temperature sensor with integrated NV memory

TMP112 – 1.4V-Capable $\pm 0.5^\circ\text{C}$ Accuracy Digital Temperature Sensor in the Compact SOT-563 Package

TMP102 – 1.4V-Capable Temperature Sensor with I2C/SMBus Interface and Alert Function in SOT-563

Data converters (5)

Switches & multiplexers (2)

Amplifiers (2)

Power management (2)

- Simplify Integrat
- Achievin
- Processi

Wi-Fi

Sub GHz

Memory Card

AMP

User Interface

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 transimpedance amplifier with a PGA conditions signal coming from photo diode. This subsystem can be used for PPG as well as spectroscopy measurement.

[View more](#)

REFERENCE DESIGNS (7)

PRODUCTS (31)

Amplifiers (8)

(VUS>1111V) (4)

General-Purpose Op Amps (3)

Instrumentation Amplifiers (1)

Switches & multiplexers (6)

Data converters (14)

Biosensing AFEs (6)

AFE4420 – Ultra-small integrated AFE with FIFO for multisensor wearable optical heart-rate monitoring

AFE4900 – Ultra-low-power integrated AFE for wearable optical, electrical biosensing

AFE4403 – Ultra-Small Integrated Analog Front End (AFE) for Heart-Rate Monitors and Low-Cost Pulse Oximeters

AFE4400 – Integrated Analog Front End (AFE) for Heart-Rate Monitors and Low-Cost Pulse Oximeters

AFE4490 – Integrated Analog Front End (AFE) for Pulse Oximeters

UCTS (31)

t monitor

ference Design

n for medical

nal Monitoring

Reference design

Design Guide: TIDA-01614

Multiparameter Front-End Reference Design for Vital Signs Patient Monitor



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 Li-Ion battery (1.1 Ah).

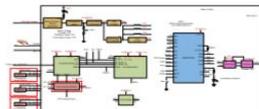
Features

- 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 2.1 F passive sensors to

Resources
TIDA-01614
AFE4403
BOJ4232
MSP430P9
ADS1292R
TMP117
TIDA-01009

Comprehensive design guides

Module (Software-action module) for detection JART interface module battery



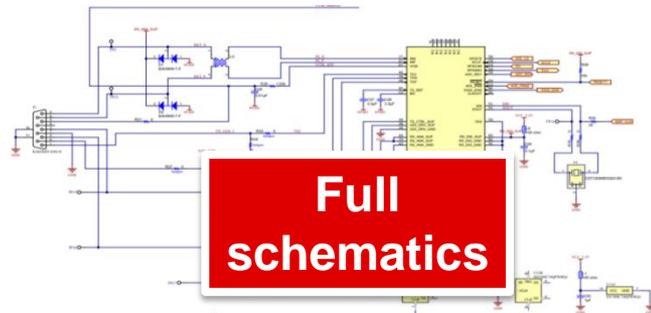
Electrocardiogram (ECG)



The following list provides details about the design:

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

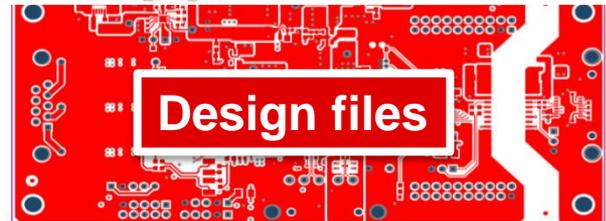
Detailed design considerations & applications info



Full schematics

How the input current limit (ILIM) is set:

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



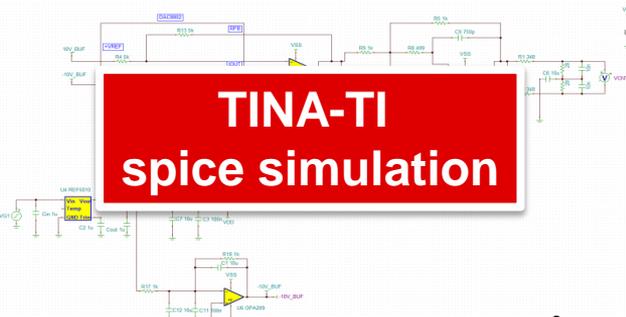
Design files

Bill of materials

Designator	Quantity	Value	PartNumber	Manufacturer	Printed Circuit Board	Description	Package/Partness
ICP1	1		TIDA-01614	TI	Printed Circuit Board		
C1, C2, C34	12	0.1µF	22050101E104K050B	TDK	04V 250V 01 µF 25 V ±5% X7R 0402		0402
C2, C3, C37, C41	4	100µF	GRM32ER60A100M050	GRM	100µF 50V 20% X7R 0603		0603
C4	1	0.1µF	0402		0402		0402
C5	1	0.1µF	0402		0402		0402
IC1	1	AFE4403	AFE4403	TI	AFE4403		0603
C11, C13, C24	6	100µF	GRM32ER60A100M050	GRM	100µF 50V 20% X7R 0603		0603
C15, C16	2	100µF	GRM32ER60A100M050	GRM	100µF 50V 20% X7R 0603		0603
IC2	1	ADS1292R	ADS1292R	TI	ADS1292R		0603
IC3	1	AFE4403	AFE4403	TI	AFE4403		0603
IC4	1	AFE4403	AFE4403	TI	AFE4403		0603
IC5	1	AFE4403	AFE4403	TI	AFE4403		0603
IC6	1	AFE4403	AFE4403	TI	AFE4403		0603
IC7	1	AFE4403	AFE4403	TI	AFE4403		0603
IC8	1	AFE4403	AFE4403	TI	AFE4403		0603
IC9	1	AFE4403	AFE4403	TI	AFE4403		0603
IC10	1	AFE4403	AFE4403	TI	AFE4403		0603
IC11	1	AFE4403	AFE4403	TI	AFE4403		0603
IC12	1	AFE4403	AFE4403	TI	AFE4403		0603
IC13	1	AFE4403	AFE4403	TI	AFE4403		0603
IC14	1	AFE4403	AFE4403	TI	AFE4403		0603
IC15	1	AFE4403	AFE4403	TI	AFE4403		0603
IC16	1	AFE4403	AFE4403	TI	AFE4403		0603
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IC63	1	AFE4403	AFE4403	TI	AFE4403		0603
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IC65	1	AFE4403	AFE4403	TI	AFE4403		0603
IC66	1	AFE4403	AFE4403	TI	AFE4403		0603
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IC87	1	AFE4403	AFE4403	TI	AFE4403		0603
IC88	1	AFE4403	AFE4403	TI	AFE4403		0603
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IC94	1	AFE4403	AFE4403	TI	AFE4403		0603
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IC98	1	AFE4403	AFE4403	TI	AFE4403		0603
IC99	1	AFE4403	AFE4403	TI	AFE4403		0603
IC100	1	AFE4403	AFE4403	TI	AFE4403		0603



Comprehensive test results



TINA-TI spice simulation



Boards available for evaluation

Patient monitoring market trend



Remote monitoring enhances quality of care and reduces healthcare cost

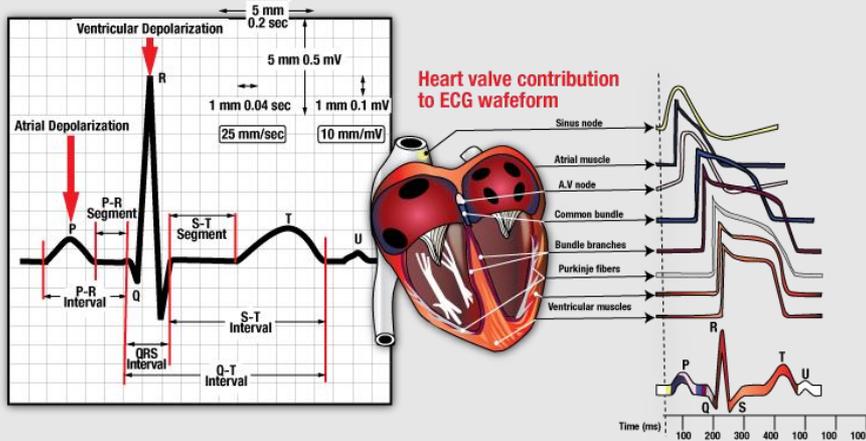
Wearable wireless medical technology enables accurate and reliable data in a smaller form factor: multi-modalities, longer battery life, SHIP mode

Artificial Intelligence uses analytics and big data to improve decision making and early prevention

Patient monitoring basics

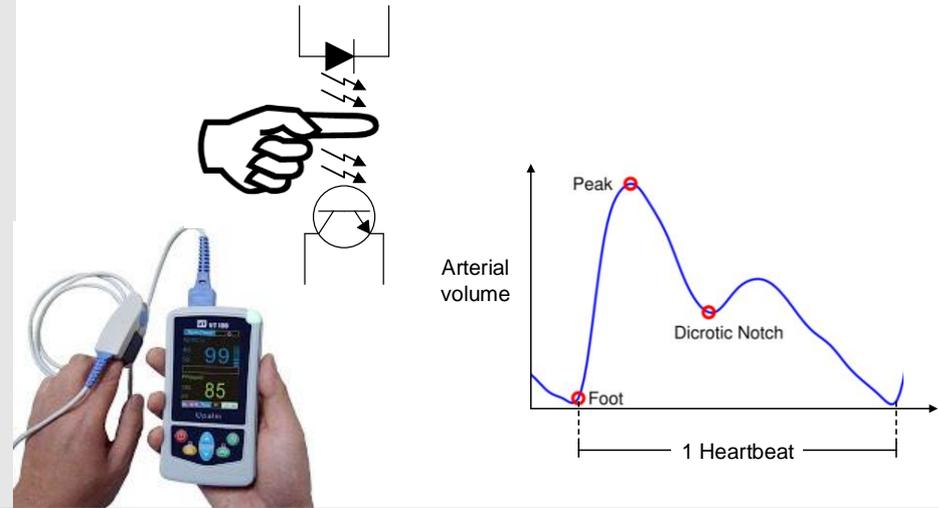
The electrocardiogram (ECG)

measures electrical activity of the heart



Photoplethysmography (PPG)

is an **optical** measurement of an organ's volume.



ECG vs. PPG

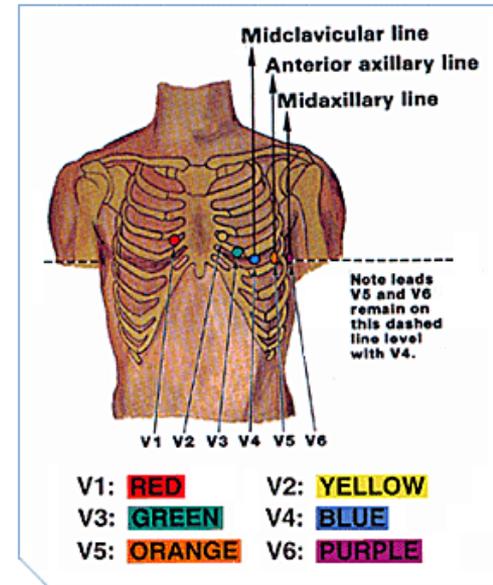
Feature Description	ECG	PPG
Measurement type	Electrical	Optical
Sensor type	Electrodes	Photodiode
Can measure heart rate?	Yes	Yes
Diagnostic information	Yes	Yes
Minimum number of skin contacts required?	2 (Across chest)	1 (Finger or wrist)
Number of ADC channels required	≥ 1	1

ECG lead and ADC channels

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

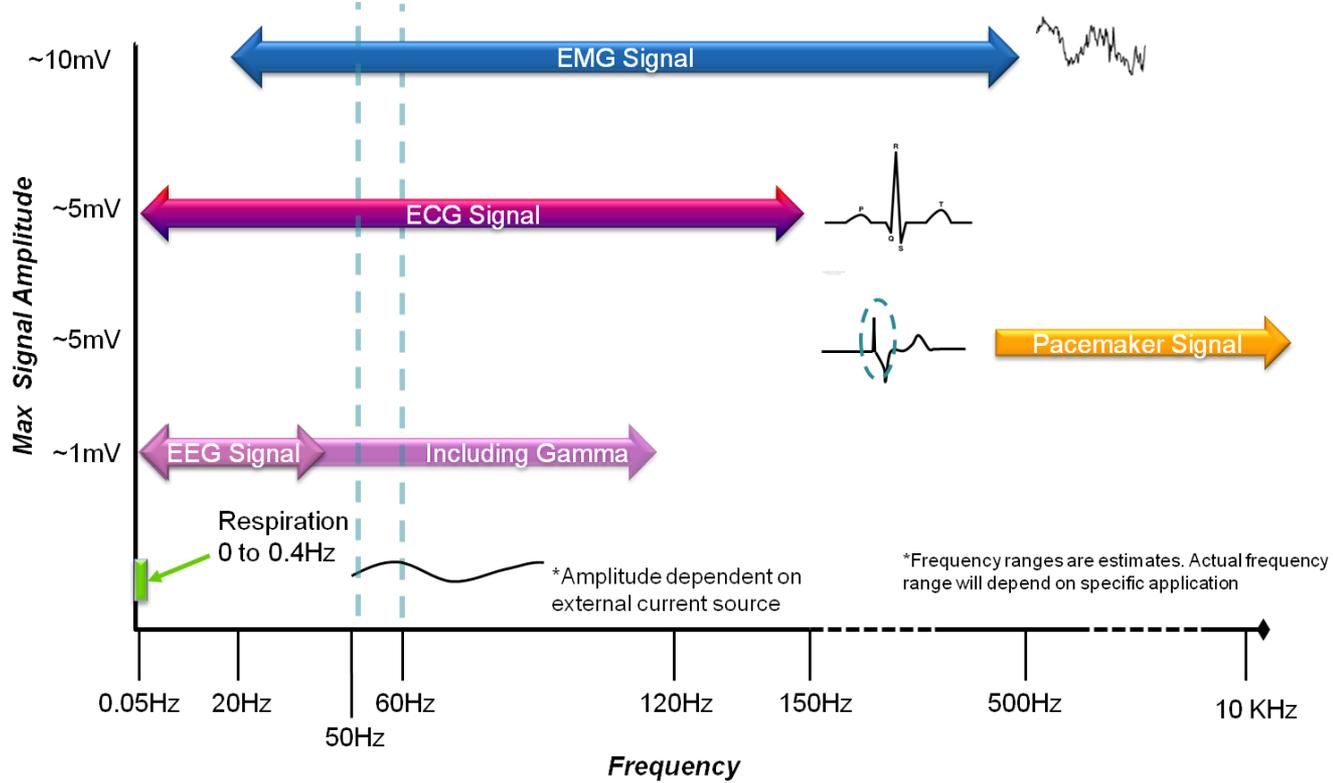
Standards Electrodes Needed

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

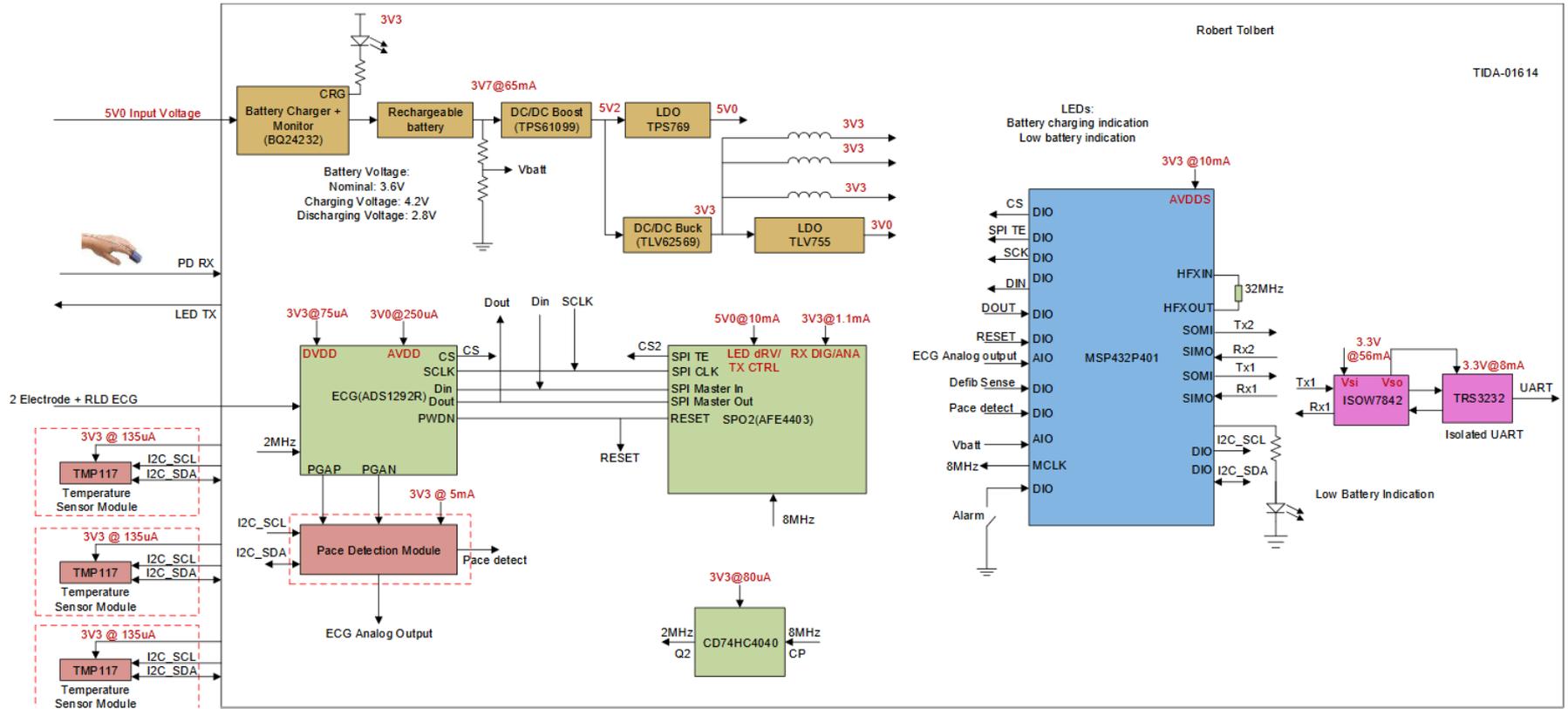


Alternating Current (AC) Interference

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

Detailed block diagram for TIDA-01614



Robert Tolbert

TIDA-01614

Design challenges TIDA-01614 solves

Design challenge 1

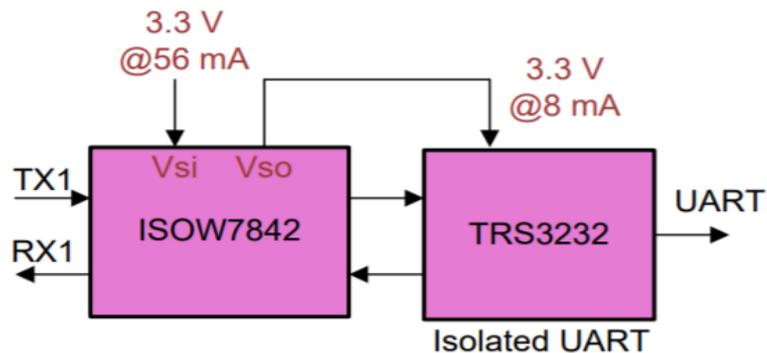
Integration of multiple modalities at optimum SNR levels and small form factor

- 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

Isolated UART interface using an onboard MSP432P401, ISOW7842, TRS3232



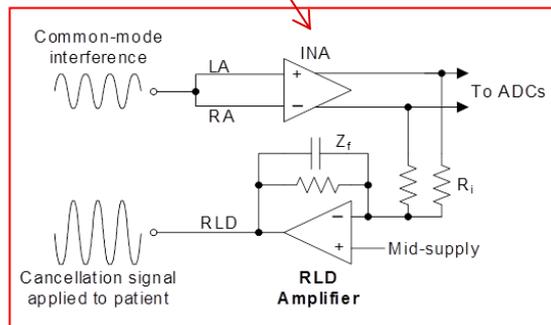
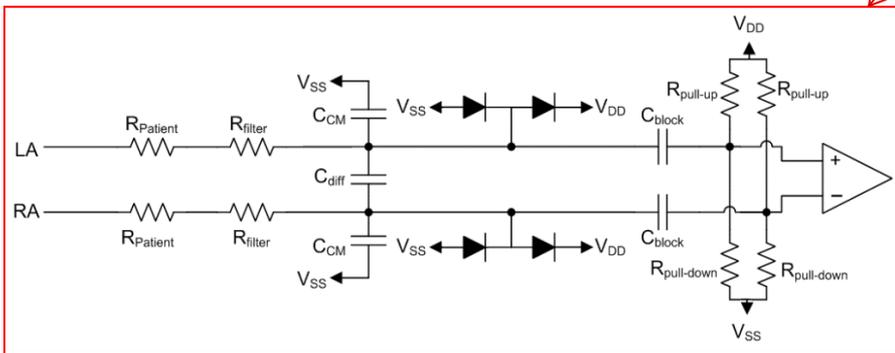
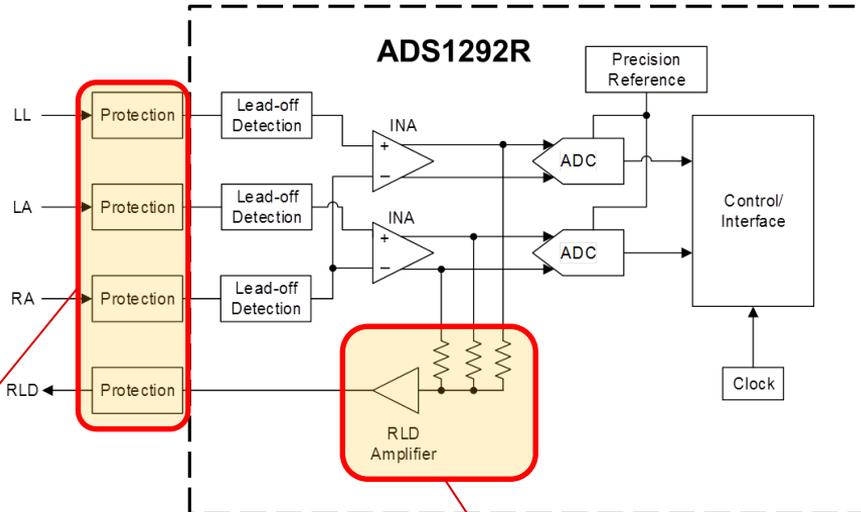
ECG analog front end



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

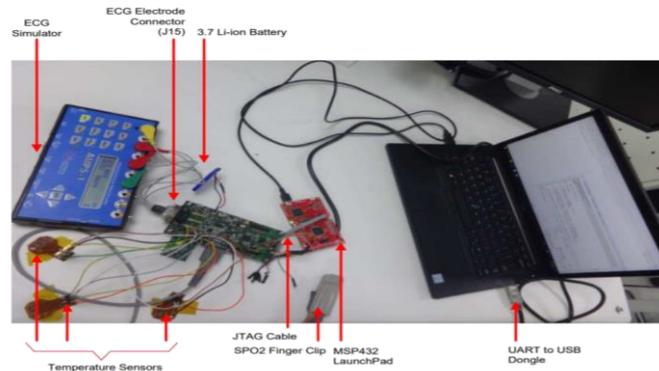


TIDA-01614 test setup and test results

Design specs

CHARACTERISTICS	SPECIFICATIONS
ECG	One lead ECG operation with RLD. Sampling rate of 500 samples per second, supports ECG sensitivity of 100 μ V
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 μ s
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



Test pacemaker detection with TIDA-010005 & TIDA-01614



TIDA-01580

Wearable, wireless, multiparameter patient monitor reference design

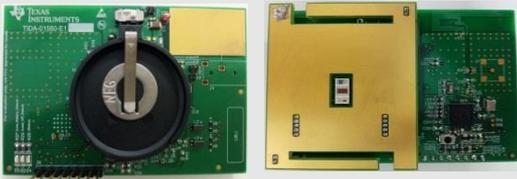
Features

- 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

Target applications

- [Wireless patient monitor](#)
- [Wearable fitness & activity Monitor](#)
- [Pulse Oximeter](#)
- [ECG](#)

Tools & resources

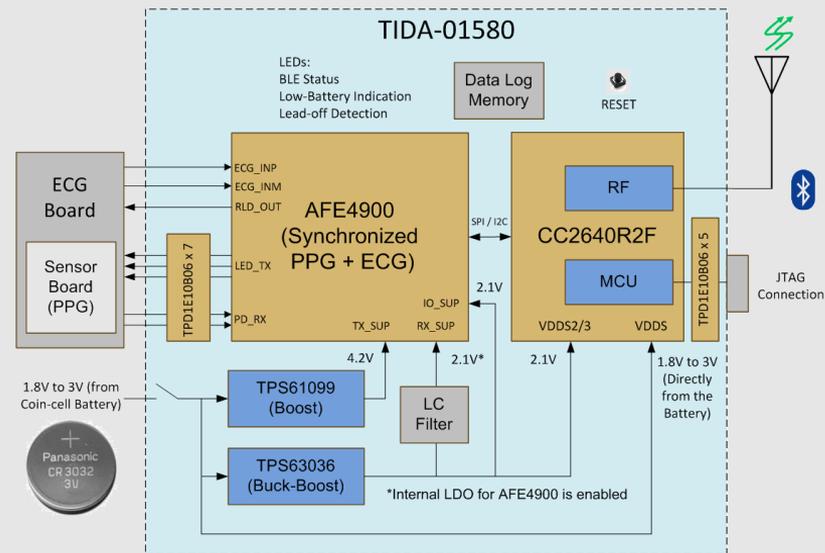


Device Datasheets:

- [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



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TIDA-01580 for medical patch

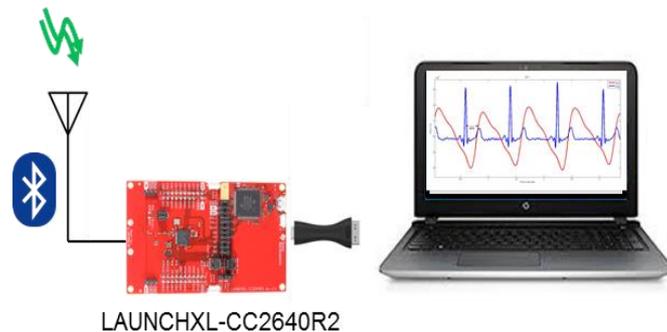


Bottom side is touching the wrist of one hand (ELECTRODE 1)

Other hand is touching the PAD on the top layer of the main board. (ELECTRODE 2)



Side View



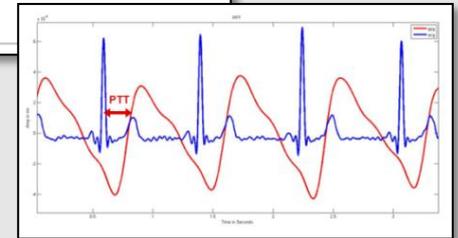
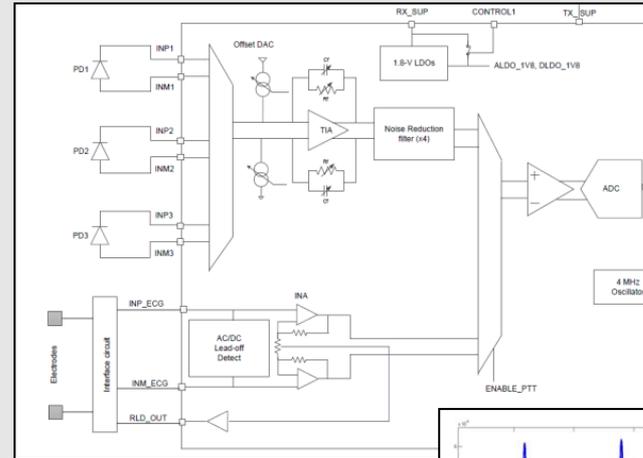
- LAUNCHXL-CC2640R2F receives the signals remotely and displays on LabView GUI
- The design uses BLE 5.0 with an advertising time = 100ms

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)

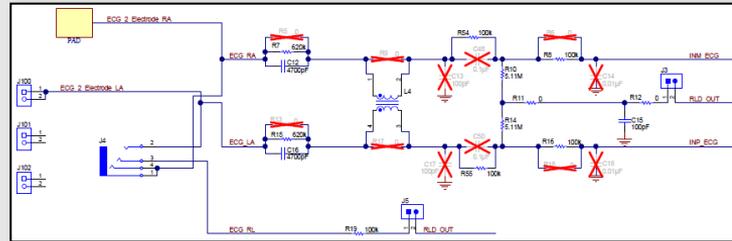
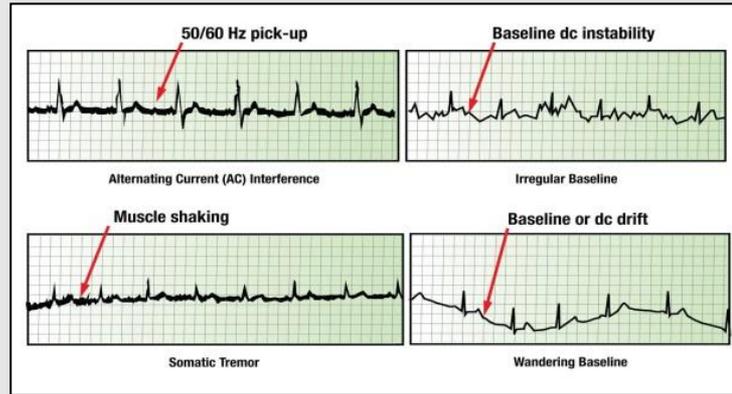


Design challenges TIDA-01580 solves

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

- Selecting the extended battery (rechargeable cells)
- Powering the device instead (bypass mode)
- Sleep / shutdown for radio device
- Selection of termination (important!)

Analog Design Journal

<http://www.ti.com/lit/an/slyt763/slyt763.pdf>

Power

Improving battery life in wearable patient monitors and medical patches

By Sanjay Pithadia

System Engineer, Medical Sector, System Engineering and Marketing

Introduction

The market for wearable patient monitors is growing fast. The two main attributes for wearable monitors are portability (or size) and operating time (or battery life). Today's wearable medical products not only measure vital signs but can also act as personal emergency-response systems.

Portable and wearable applications are typically battery powered, and for consumers, battery life is one of the key purchasing considerations. The life of the battery is critical because most patient monitors measure and monitor continuously.

Battery-powered systems require careful partitioning, tight space utilization and efficient use of the available charge. It is important to enable more functionality while delivering power more efficiently in a tight space for a longer time. Functions like standby, sleep, power save, hibernate and shutdown are critical for designers to

hydrate (NiMH), lithium iron phosphate, lithium manganese and zinc are popular battery chemistries in medical devices, and each type needs a different charging circuit. It is also important to note that rechargeable batteries have a self-discharge rate. To reduce overall bill of materials (BOM) and size, designers may connect batteries directly to the radio module and other peripherals, but running directly from the battery voltage is not the most efficient way to use the battery.

Choosing the right battery charger to improve battery life

Battery charging for wearables is challenging because batteries must be both small in size and capacity. Charge currents vary greatly depending on whether a 50-mAh, 100-mAh or 200-mAh battery is used, and whether to charge at 0.5 C-rate (C), 1 C or 2 C. The key is to include



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

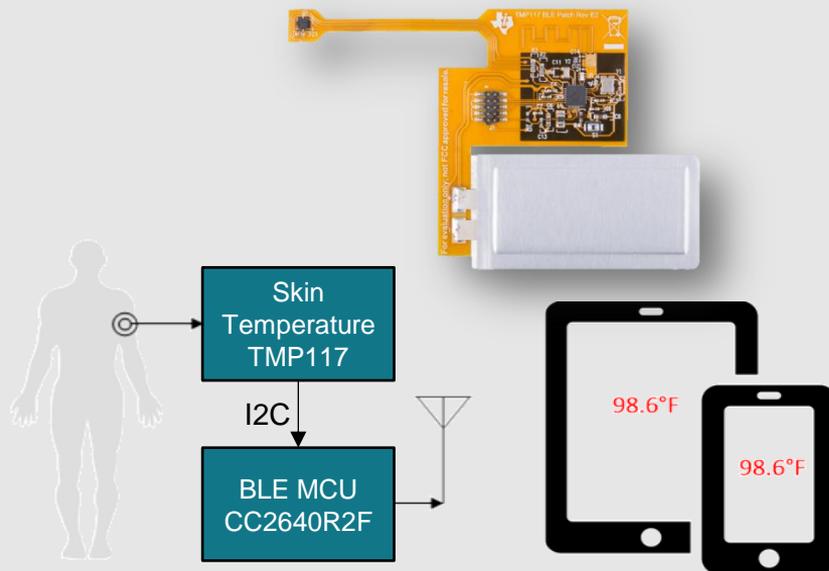
- [Medical Sensor Patches](#)
- [Multiparameter Patient Monitors](#)
- [Smart Patches](#)

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 $\pm 0.1^{\circ}\text{C}$ Accuracy



TMP117x Ultra-high accuracy digital temp sensor with integrated non-volatile memory

Features

Accuracy

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

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)

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

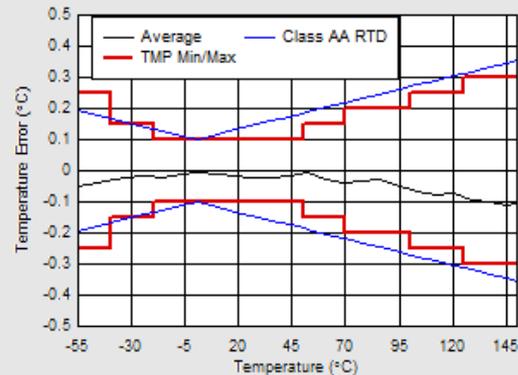
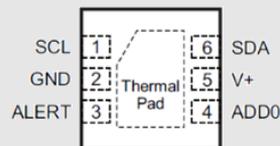
Digital feature & I2C interface

- Programmable Temperature Alert & Offset value
- Soft Device Rest

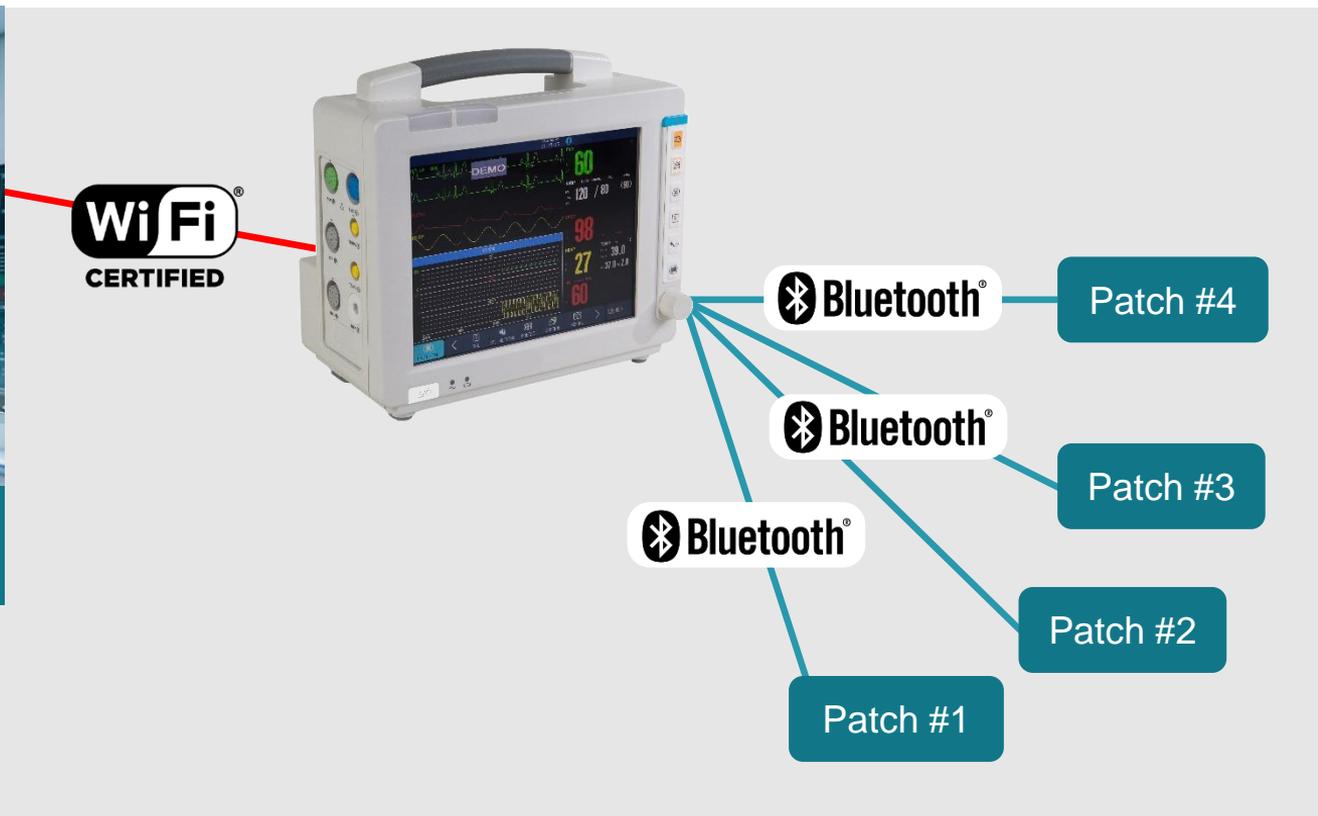
Smallest package

- 6 PIN, QFN & CSP

6-Pin WSON
Top View



Full system: Multiparameter patient monitor + wireless sensors



Why TI SimpleLink™ for multiparameter 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



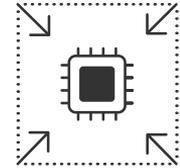
- CC3135/CC3235 Wi-Fi modules
- 5GHz Wi-Fi to reliably connect to hospital network
- BLE multi-role support, up to 32 simultaneous connections

Secure



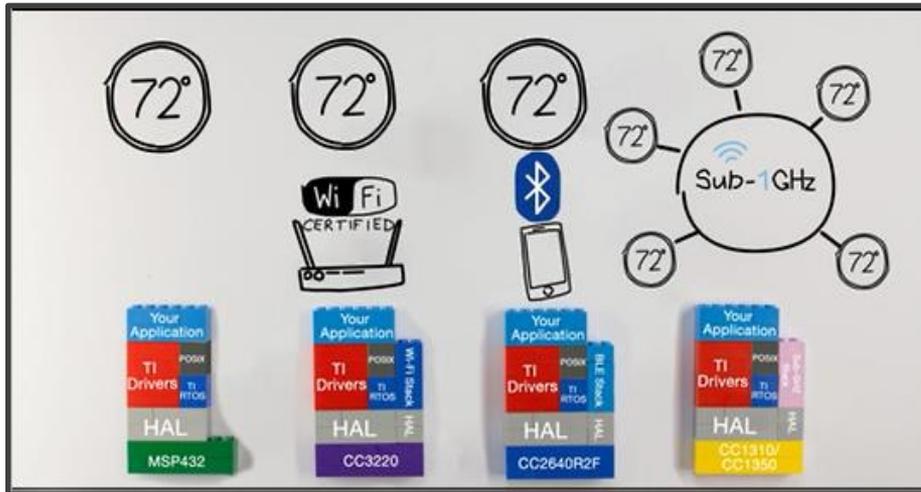
- FIPS 140-Level 1 validation
- Offload CPU bandwidth – HW crypto accelerators
- Secure boot

Small size



- BAW: First crystal-less wireless BLE SoC – 12% area savings in reference design
- Tiny BLE SoC: CC2640R2F – 2.7mm x 2.7mm DSBGA

Invest once, reuse effortlessly



- [Learn more about SimpleLink code portability](#)
- [SimpleLink Medical Resources](#)
- [CC2640R2F: How do I design an accurate and thermally efficient wearable temperature monitoring system?](#)

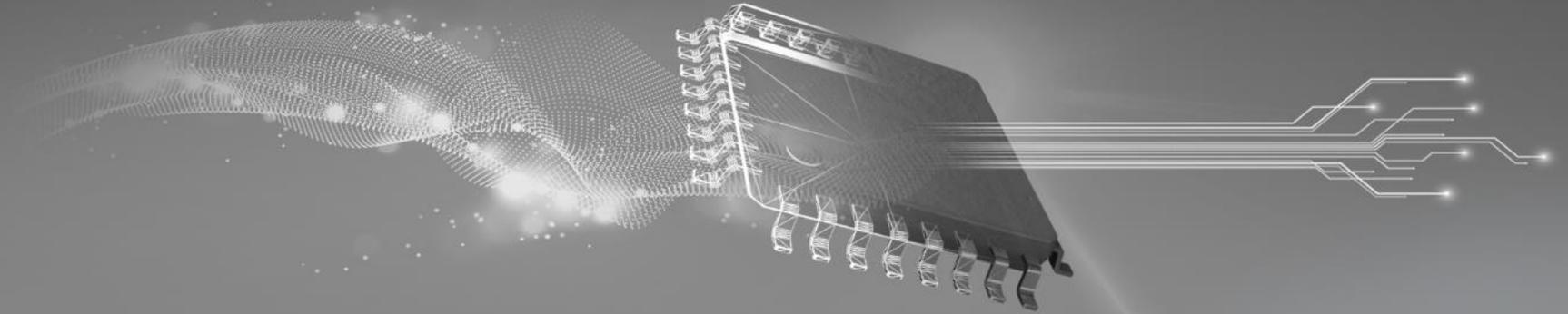
100% code reuse

 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

Common software



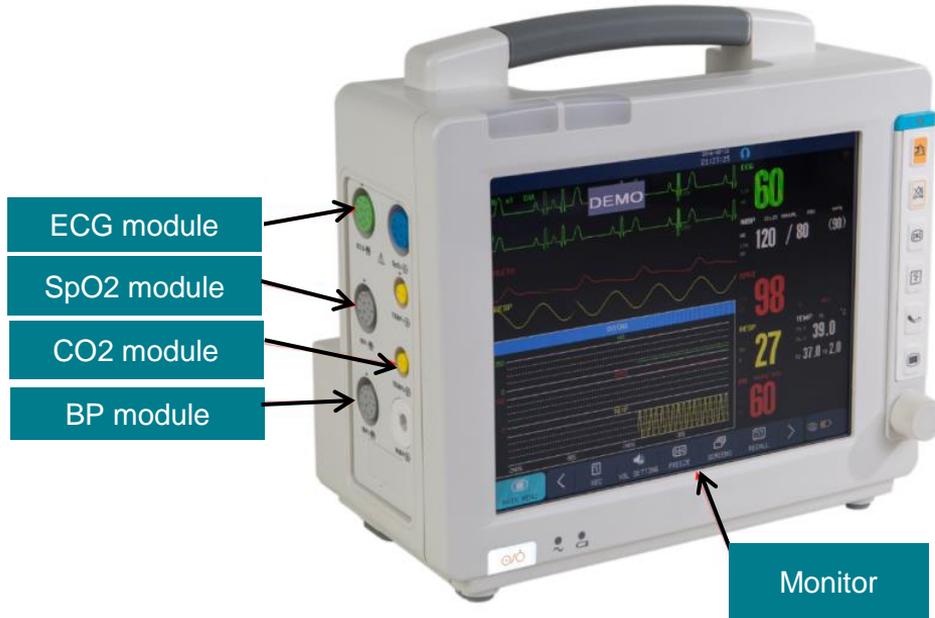
TI TECH DAYS



Achieving isolation and enabling patient safety

Patient safety

- *Patient safety is a global health priority. Recalling resolution WHA55.18 (2002), which urged Member States to “pay the closest possible attention to the problem of patient safety and to establish and strengthen science-based systems, necessary for improving patients’ safety and the quality of health care”, the seventy-second World Health Assembly (WHA72), in May 2019, adopted WHA72.6, a resolution on ‘Global action on patient safety’.* (Source: <https://www.who.int/patientsafety/en/>)

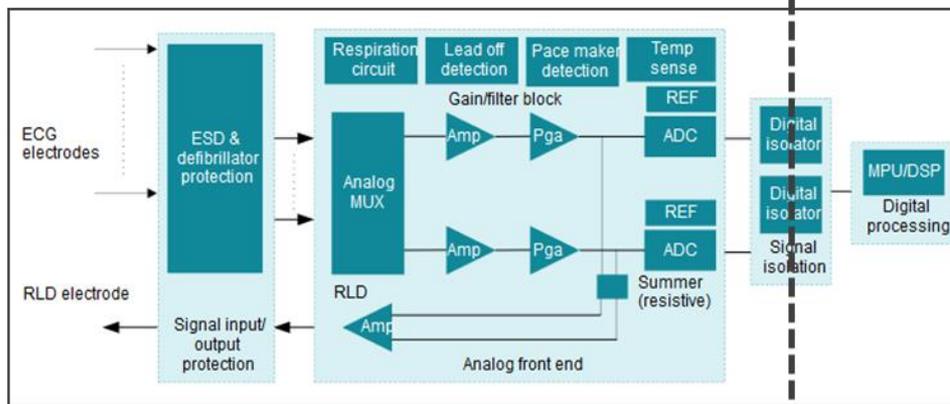
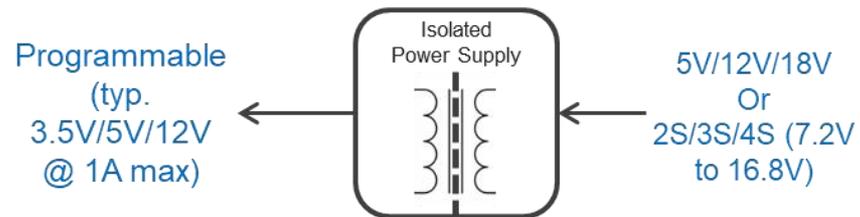


Isolation requirements and safety limits

- IEC60601-1: International basic safety and essential performance standard for electrical medical equipment and medical electrical systems.
 - Regional compliance
 - Editions and versions
- Levels of isolation – patient focus
- Spacing – creepage & clearances
- Safety insulation for transformers
- Leakage current limits
 - Isolation at the sensing side
 - Isolation at the data/power side

Data and power isolation

Characteristic	Value
Input voltage range	Option – 1: 3.3 V to 24 V from AC/DC power supply Option – 2: From 1S-4S battery (3.7 V to 16 V)
Output Voltage	Option – 1: 3.3 V or 5 V Option – 2: 3.5 V or 5.5 V to be followed by an Low Drop-out Regulator (LDO)
Output power	Typical 5 watts to 7 watts
Isolation	5 kV and above



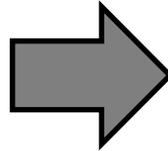
ECG module example

5kV Isolation

Key design challenges

- Input voltage ranging from 3.3V to 24V
 - Regulated input vs. non-regulated input
- Output voltage ranging from 3.3V to 6V
- Output power up to 5W
- Open-loop or closed-loop (voltage/current)
 - achieving < 1% load regulation
- Isolation ~1kV to 5kV
- Emission (CISPR22/25, IEC60601-1)
- Small form factor (New trend – electronics in cable and portable MPMs)
 - reduced BoM
- Low cost

One size doesn't fit all the requirements

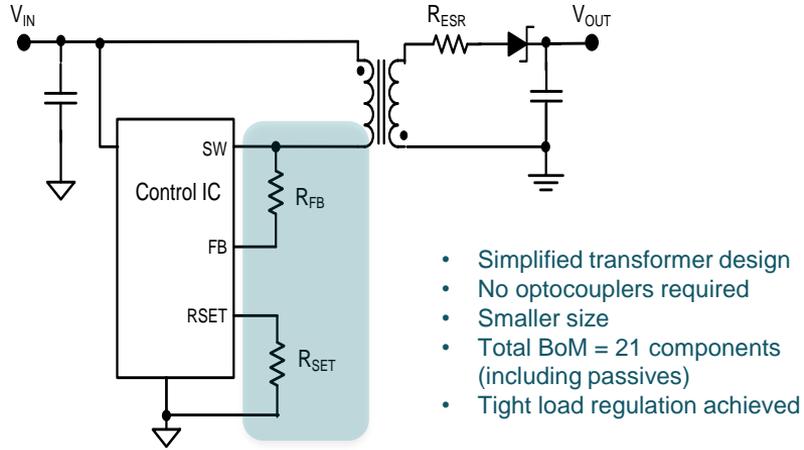


Possible Architectures

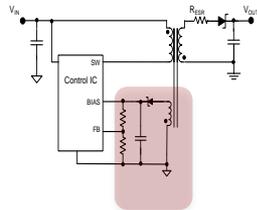
- Flyback
- Push-pull
- Isolated power module
- Isolated power and data module

PSR flyback topology

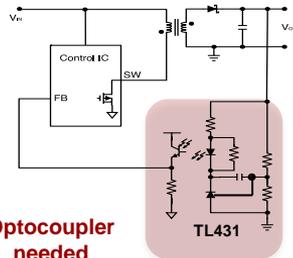
Primary-side regulated flyback



Conventional Flyback



Tertiary feedback winding needed



Optocoupler needed

Parameter	Value
Input voltage (V _{in})	4.5V to 65V (70V max)
Output voltage (V _{out})	Adjustable
Output power (P _{out})	7W max
Isolation level	5kV (can be tuned as per transformer design)
Size	45mm x 25mm x 11mm (Depends on transformer design)
Output regulation	1% achievable

Suggested TI devices:
LM5180
LM25180

Refer to “Design Calculator” for complete schematics, BoM and simulation results



Design Calculator

Design calculator for LM25180

Reliable Power for Demanding Systems

LM25180 PSR Flyback Converter Design Tool

About
 = Input Box
Terms Of Use

Step 1: Operating Specifications

Input Voltage - Min. $V_{IN(min)}$	7 V
Input Voltage - Nom. $V_{IN(nom)}$	12 V
Input Voltage - Max. $V_{IN(max)}$	16 V
Single Output or Dual Outputs	DUAL
Output Voltage, V_{OUT1}	5 V
Rated Output Current, I_{OUT1}	0.5 A
Output Voltage, V_{OUT2}	-12 V
Rated Output Current, I_{OUT2}	0.2 A

Step 2: Flyback Transformer

Minimum Magnetizing Inductance	27 μ H
Magnetizing Inductance, L_{MAG}	30 μ H
Primary Winding DCR	100 m Ω
Secondary Winding #1 DCR	100 m Ω
Secondary Winding #2 DCR	100 m Ω
Pri-Sec Leakage Inductance	200 nH
Turns Ratio, PRI : SEC1	3:1
Turns Ratio, SEC1 : SEC2	2:33
Duty Cycle at $V_{IN(min)}$	69.4 %
Max Output Power at $V_{IN(min)}$	3.16 W

Step 3: Input & Output Capacitors

Minimum Input Capacitance	2.2 μ F
Input Capacitance, C_{IN}	38 μ F
Input Capacitor ESR	5 m Ω
Resulting Input Voltage Ripple	26 mV _{pk-pk}
Minimum Output Capacitance, Output #1	36.3 μ F
Output Capacitance, C_{OUT1}	100 μ F
Output Capacitor ESR	3 m Ω
Resulting Output Voltage Ripple, Output #1	35 mV _{pk-pk}

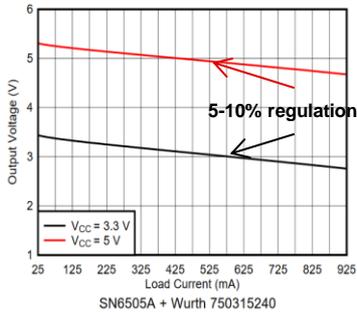
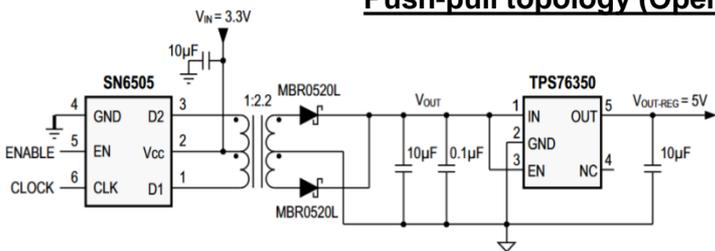
Minimum Output Capacitance, Output #2	6.0 μ F
Output Capacitance, C_{OUT2}	47 μ F
Output Capacitor ESR	3 m Ω
Resulting Output Voltage Ripple, Output #2	29 mV _{pk-pk}

Step 4: Feedback, Soft-start, TC, UVLO

Recommended Feedback Resistor	157.5 k Ω
Selected Feedback Resistor, R_{FB}	158 k Ω
Soft-Start Configuration	Adjustable
Soft-Start Time	10 ms
Soft-Start Capacitance, C_{SS}	47 nF
V_{OUT} Thermal Compensation	NO
*Leave TC Pin Open	
Input UVLO Configuration	Adjustable
Input UVLO Turn-On Threshold	6 V
Input UVLO Turn-Off Threshold	5 V
Upper UVLO Resistor, R_{UV1}	158 k Ω
Lower UVLO Resistor, R_{UV2}	52.3 k Ω

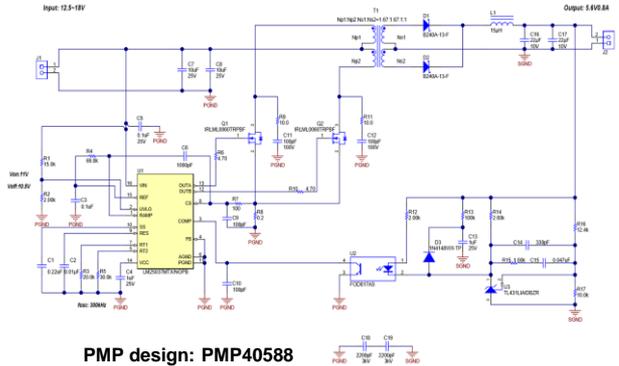
Push-pull topology

Push-pull topology (Open-loop)



- No opto-couplers required
- Smaller size, total BoM = 10 components (including passives)
- Needs regulated input

Push-pull topology (Closed-loop)



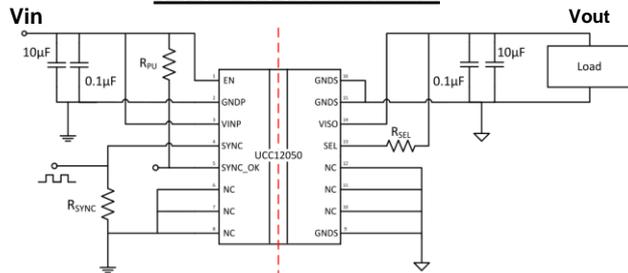
- Tight output regulation due to feedback
- Total BoM = 46 components (including passives)
- Optocoupler based design – reliability

Parameter	Value
Input voltage (Vin)	2.2V to 5.5V
Output voltage (Vout)	5V unregulated
Output power (Pout)	5W max
Isolation level	5kV (can be tuned as per transformer design)
Size	30mm x 25mm x 6mm (Depends on transformer design)
Output regulation	5 to 10%

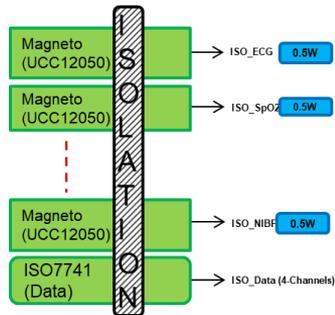
Suggested TI devices:
 SN6505A
 SN6505B

Isolated power module

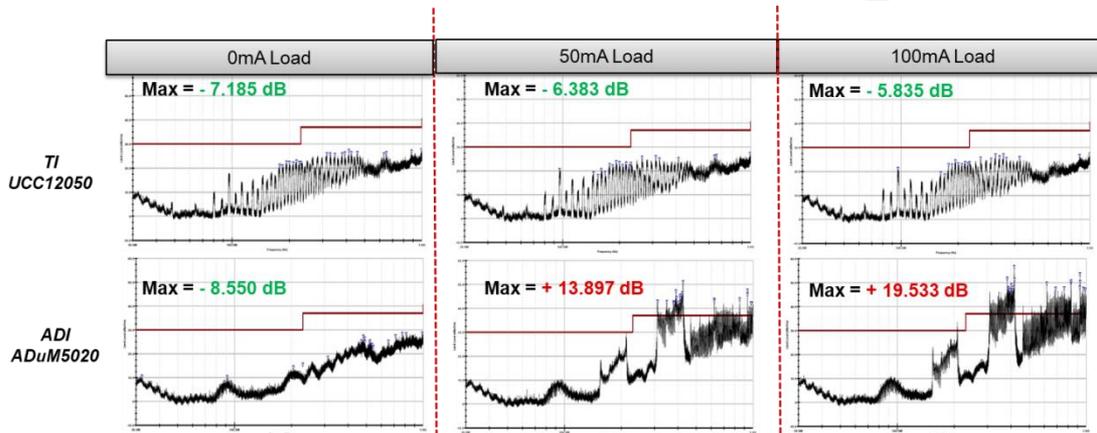
UCC12050 schematic



Scalability



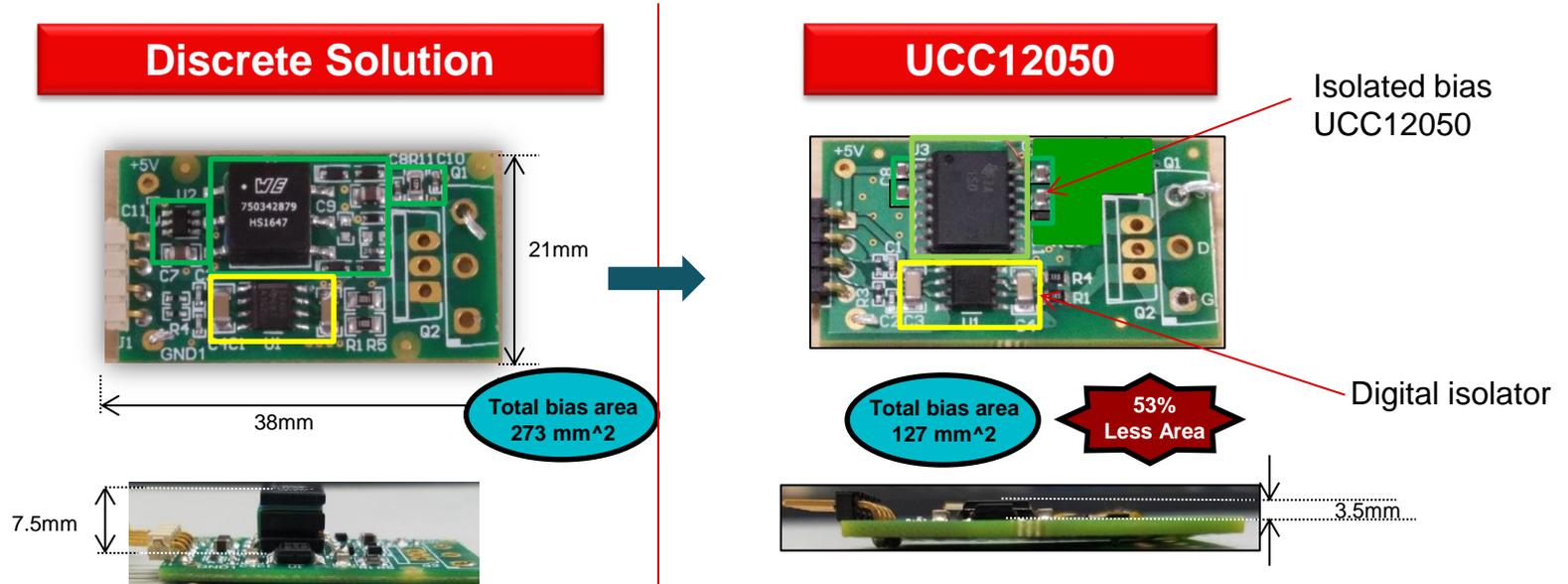
Parameter	Value
Input voltage (Vin)	4.5V to 5.5V
Output voltage (Vout)	Regulated 3.3V or 5V
Output power (Pout)	0.5 W
Isolation level	5kV RMS reinforced
Size	10.3mm x 7.5mm x 2.65mm
Output regulation	1.5%



Same (apple-to-apple) EVM configuration: [no ferrite beads](#), [no LDO](#), [no stitch capacitors](#), on [2 layer PCB](#)
 Tested to CISPR32 Limit, in 10m chamber, on same day, in same certified lab.

Suggested TI device:
 UCC12050

Integrated transformer technology benefits

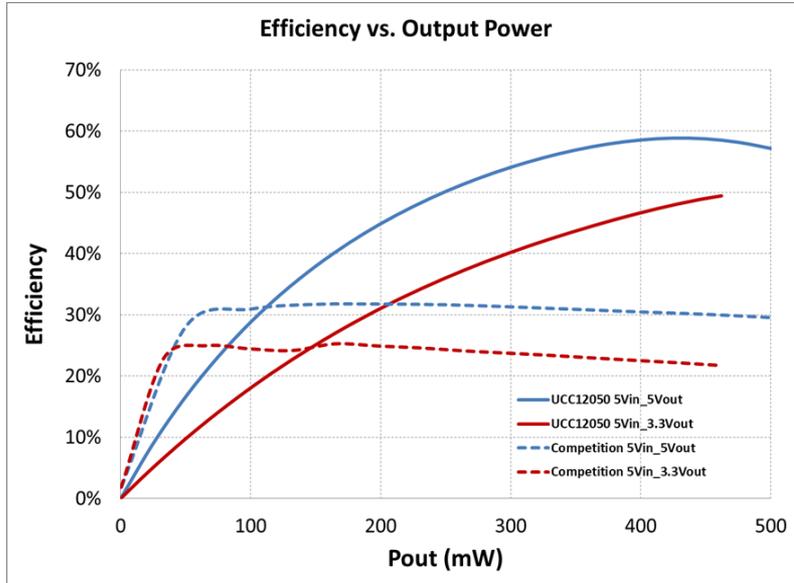


Single chip solution (UCC12050) advantages:



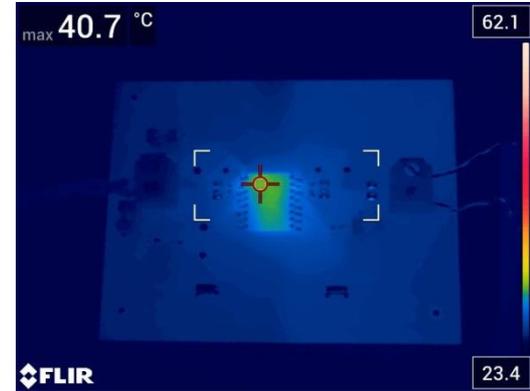
- ✓ Smaller size and low profile
- ✓ Very low isolation capacitance C_{ps} for better CMTI and less noise
- ✓ Simplify design with less components and easy board layout

Efficiency and thermal Image

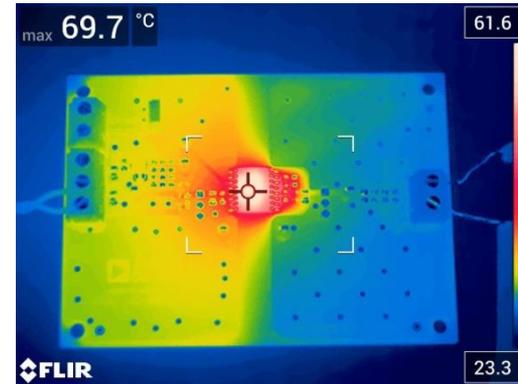


- Thanks to the 2X peak efficiency, temperature rise of magnetic core solution is $\sim 30^{\circ}\text{C}$ lower than air-core solution when operating at $5 V_{IN}/5 V_{OUT} 100 \text{ mA}$

Magnetic core (UCC12050)

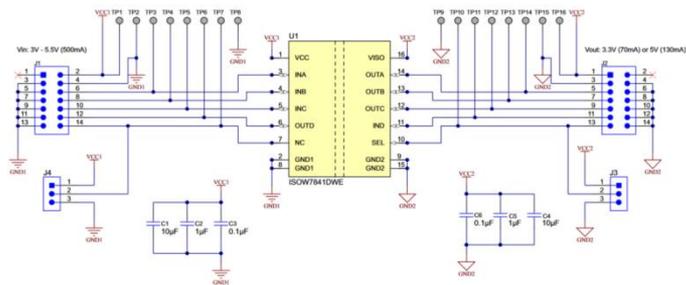


Air core

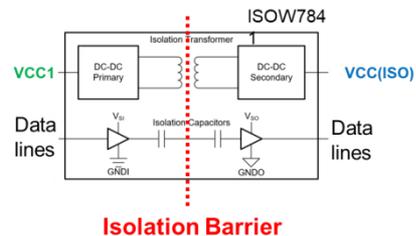


ISOWatt – Isolated power and data

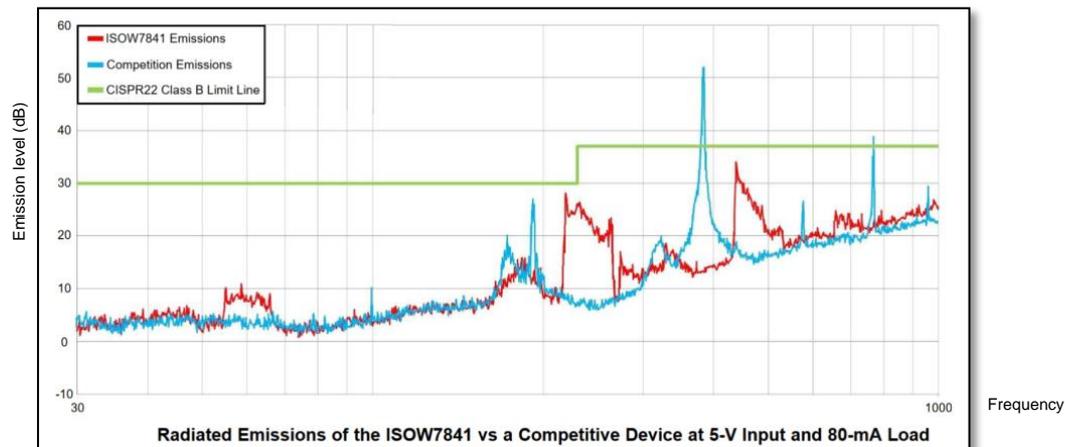
ISOW7841 schematic



Integrated isolated power & data



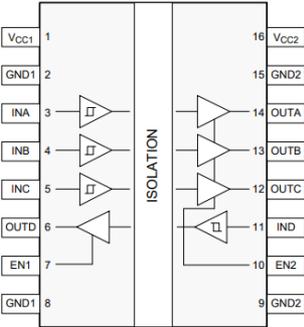
Parameter	Value
Input voltage (Vin)	3V to 5.5V
Output voltage (Vout)	Regulated 3.3V or 5V
Output power (Pout)	0.65 W
Isolation level	5kV RMS reinforced
Size	10.3mm x 7.5mm x 2.65mm
Output regulation	1%



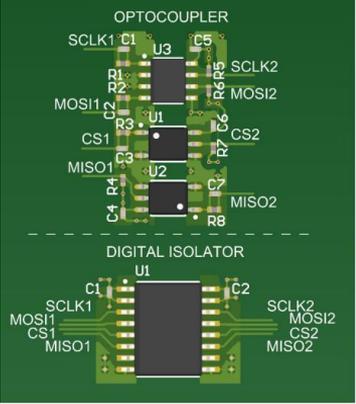
Suggested TI device:
ISOW7841
ISOW7821

Digital isolators – signal isolation

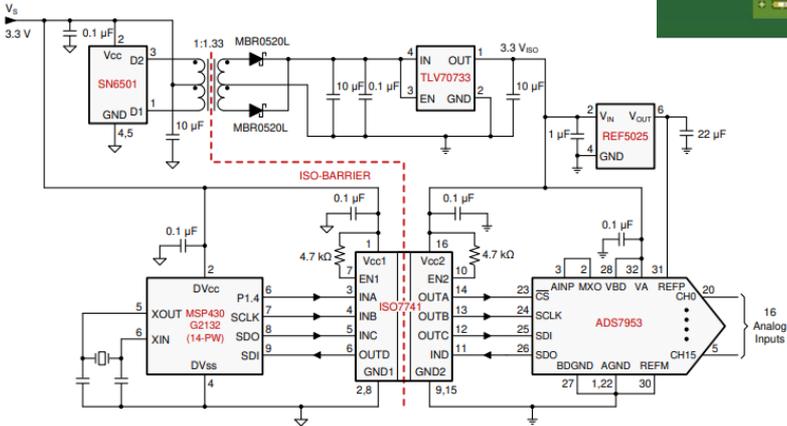
ISO7741DW & ISO7841DWW



SPI Isolation: ISO7741DW vs traditional optocoupler solution



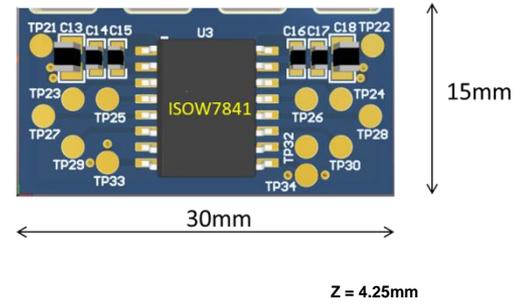
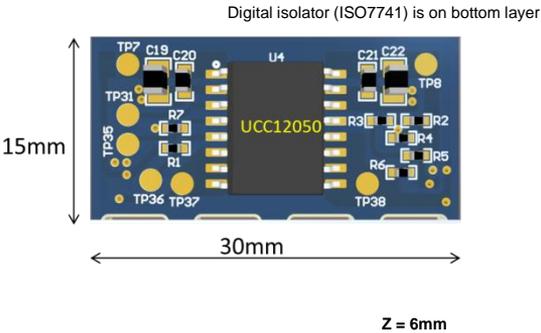
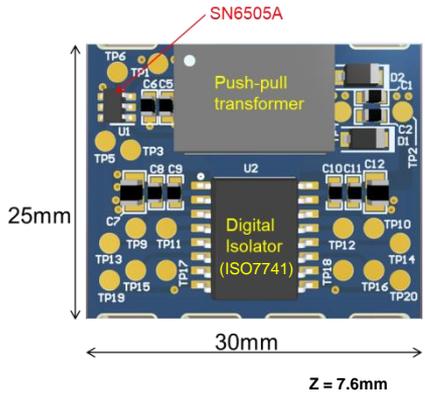
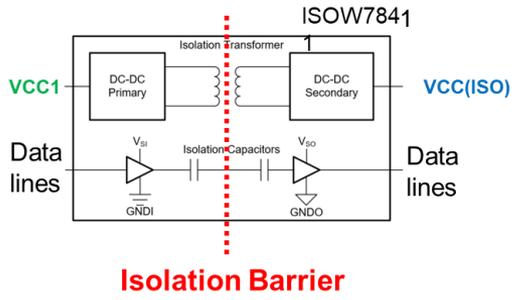
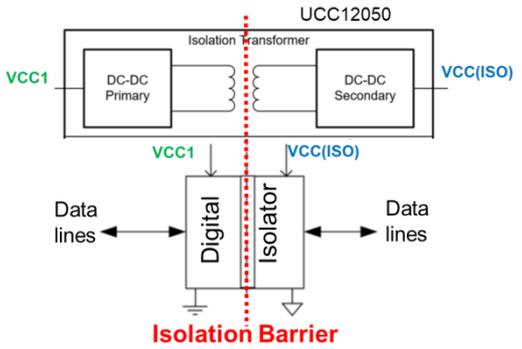
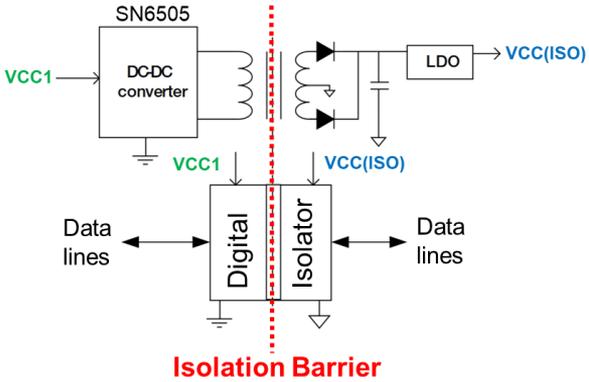
Application diagram:



Parameter	ISO7741DW	ISO7841DWW
Viso	5kVrms	5.7kVrms
Creepage/Clearance	8 mm	14 mm
Data rate	100 Mbps	100 Mbps
IEC 60601-1 Capability	2 MOPP up to 240Vrms	2 MOPP up to 400Vrms
Size	10.3 x 7.5 mm	10.3 x 14.0 mm

Suggested TI device:
 ISO7741DW
 ISO7841DWW

Layout comparison – power and 4-ch data isolation



Summary

Topology Parameter	Conventional flyback	PSR flyback (LM25180)	Open-loop push-pull (SN6505)	Closed-loop push-pull (LM25037)	Isolated power module (UCC12050)	Isolated power with digital isolator (ISOW7841)
Output power level	Flexible (transformer and PWM controller dependent)	5 W to 7 W	5 W	Flexible (transformer and PWM controller dependent)	0.5 W	0.65 W
Input voltage range	Up to 42V/65V	Up to 42V/65V	Up to 5.5V	Up to 75V	Up to 5.5V	Up to 5.5V
Output regulation	1% or less	1%	5 to 10%	1% or less	1.5%	1%
No. of discrete components	More than 30	21	10	46	Less than 10	Less than 10
Isolation rating	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	Flexible (Transformer dependent)	5000 Vrms Reinforced	5000 Vrms Reinforced
Emission	High	High	Low	High	Low	Moderate to high

Application Report

- <http://www.ti.com/lit/an/sloa285a/sloa285a.pdf>

Application Report

Topology Selection for Isolated Power Supplies in Patient Monitor



Sanjay Pithadia

ABSTRACT

Multiparameter Patient Monitors measure vital signs and use isolated modules for achieving the patient safety. These modules are small in size as they are inserted into the main monitor and support up to 5kV isolation. The data and power both are isolated using digital isolators and isolated power supplies, respectively. This application report talks about different topologies for isolated power and data. It dwells deeper into the critical design challenges associated with isolated power and data such as output regulation, feedback mechanism, input voltage range, output power and size considerations along with suitable power architectures. Finally, it compares the topologies on the basis of all these different parameters.

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

2,785

Contributing TI employees

295,218

Issues resolved

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Forums

Blogs

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...



Audio forum

Patopat23

10/22/2018 6:37:32 AM

0 Views | 0 replies

Top contributors



YiKai Chen
574855 points



Jens-Michael
Gross
227195 points





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