Design wearable healthcare systems with advanced sensing and efficient power for improved patient monitoring.

Sanjay Pithadia
4 March 2021

Sanjay Pithadia
Patient Monitoring

Design wearable healthcare systems with advanced sensing and efficient power for improved patient monitoring.
Agenda

- TI in medical
- Market trends
- Fundamentals and challenges
- Reference designs
TI semiconductors in every medical category
Medical sector page

- Medical equipment
  - Anesthesia delivery system
  - Chemistry/gas analyzer
  - Dialysis machine
  - Electronic hospital bed & bed control
  - Infusion pump
  - Medical accessories
  - Medical chair & table
  - Motorized electronic wheelchair
  - Surgical equipment
  - Ventilator

- Patient monitoring & diagnostics
  - Clinical digital thermometer
  - Digital stethoscope
  - Electrocardiogram (ECG)
  - Endoscope
  - Eye, ear, nose & throat exam
  - Medical sensor patches
  - Mother & neonatal care monitor
  - Multiparameter patient monitor
  - Pulse oximeter
  - Sleep diagnostics

- Home healthcare
  - Blood glucose monitor
  - Blood pressure monitor
  - CPAP machine
  - Electronic thermometer
  - Hearing aid
  - Nebulizer
  - Oxygen concentrator
  - Telehealth systems

- Imaging
  - CT & PET scanner
  - MRI
  - Ultrasound scanner
  - Ultrasound smart probe
  - X-ray systems

- Personal care & fitness
  - Beauty & grooming
  - Electric toothbrush
  - Fitness machines
  - Wearable fitness & activity monitor
## 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.

#### REFERENCE DESIGNS (11)

- Sensors (4)
  - Analog Temperature Sensors (1)
  - Digital Temperature Sensors (3)

<table>
<thead>
<tr>
<th>Reference Design</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMP117</td>
<td>±0.1°C accurate digital temperature sensor with integrated NVRAM memory</td>
</tr>
<tr>
<td>TMP112</td>
<td>±0.5°C capable digital temperature sensor in the compact SO-8 package</td>
</tr>
<tr>
<td>TMP102</td>
<td>±1°C capable temperature sensor with I2C/SMBus interface and alert function in SO-863</td>
</tr>
</tbody>
</table>

### PPG/Optical/Spectroscopy Front End

The optical front end has two sections: one for driving the LEDs and another for processing the signal received from photodiodes. LED drivers are operated with digital data coming from DDC and transimpedance amplifier with a PGA conditioned signal coming from photodiode. This subsystem can be used for PPG as well as spectroscopy measurement.

#### REFERENCE DESIGNS (7)

- Amplifiers (3)
  - General-Purpose OPAmp (2)
  - Instrumentation Amplifiers (1)

- Switches & multiplexers (6)

- Data converters (14)

<table>
<thead>
<tr>
<th>Reference Design</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFE4420</td>
<td>Ultra-small integrated AFE with FIFO for multisensor wearable optical heart rate monitoring</td>
</tr>
<tr>
<td>AFE4950</td>
<td>Ultra-low-power integrated AFE for wearable optical, electrical biosensing</td>
</tr>
<tr>
<td>AFE4421</td>
<td>Ultra-small integrated Analog Front End (AFE) for Heart Rate Monitors and Low-Cost Pulse Oximeters</td>
</tr>
<tr>
<td>AFE4429</td>
<td>Integrated Analog Front End (AFE) for Heart Rate Monitors and Low-Cost Pulse Oximeters</td>
</tr>
<tr>
<td>AFE4600</td>
<td>Integrated Analog Front End (AFE) for Pulse Oximeters</td>
</tr>
</tbody>
</table>
Reference design

Detailed design considerations & applications info
Comprehensive design guides
Full schematics
Design files
Bill of materials
Comprehensive test results
Boards available for evaluation

The following list provides details about the design:
- Supply Voltage = 5 V
- Charging current = 0.1 A

How the input current limit (ILIM) is set:
- RLIM = KILIM / 11-MAX
- KILIM = 1530 Aq
Remote monitoring enhances quality of care and reduces healthcare cost

Wearable wireless medical technology enables accurate and reliable data in a smaller form factor: multimodalities, 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.
<table>
<thead>
<tr>
<th>Feature Description</th>
<th>ECG</th>
<th>PPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement type</td>
<td>Electrical</td>
<td>Optical</td>
</tr>
<tr>
<td>Sensor type</td>
<td>Electrodes</td>
<td>Photodiode</td>
</tr>
<tr>
<td>Can measure heart rate?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Diagnostic information</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum number of skin contacts</td>
<td>2 (Across chest)</td>
<td>1 (Finger or wrist)</td>
</tr>
<tr>
<td>required?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of ADC channels required</td>
<td>≥1</td>
<td>1</td>
</tr>
</tbody>
</table>

**ECG vs. PPG**
## ECG lead and ADC channels

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

### Standards
- 1 Lead: LA, RA
- 3 Lead: LA, RA, LL
- 6 Leads: LA, RA, LL
- 12 Leads: LA, RA, LL, V1-6

### Electrodes Needed
- V1: RED
- V3: GREEN
- V5: ORANGE
- V6: PURPLE

![ECG lead diagram](image-url)
ECG characteristics

Frequency domain

- ECG Signal
  - ~5mV
  - Including Gamma
  - Respiration 0 to 0.4Hz
- EMG Signal
  - ~10mV
- Pacemaker Signal
  - ~5mV

*Amplitude dependent on external current source
*Frequency ranges are estimates. Actual frequency range will depend on specific application
Challenges in measuring ECG

50/60 Hz pick-up

Alternating Current (AC) Interference
Challenges in optical bio-sensing

- Low power for longer battery life
- Skin tone variation
- Best PPG signal for motion cancellation algorithms
- Performance with glass
- Low temperature performance
- Ambient light
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 0.1º Celsius accurate sensors (TMP117) to measure the skin temperature
- Enables data transfer over isolated UART interface
- Works with 3.7V Li-ion rechargeable battery
- On-board memory for data logging

**Benefits**
- Single IC does both ECG, respiration
- Pace detection
- ECG with 3 electrodes
- Three temperature sensors for temperature measurement

**Applications**
- Multiparameter patient monitor
- Medical sensor patches
- Pulse oximeter
- Electrocardiogram (ECG)
Detailed block diagram for 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 0.1º 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 test setup and test results

Design specs

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG</td>
<td>One lead ECG operation with RLD. Sampling rate of 500 samples per second, supports ECG sensitivity of 100 ( \mu )V</td>
</tr>
<tr>
<td>SPC02 Measurement</td>
<td>Works in transmissive SPO2, refresh rate of 500 Hz</td>
</tr>
<tr>
<td>Skin Temperature Measurement</td>
<td>Three temperature sensor with 0.1 degree accuracy</td>
</tr>
<tr>
<td>Pace pulse Rise-time (TR) measurement range</td>
<td>30–200 ( \mu )s</td>
</tr>
<tr>
<td>Pace pulse duration (TD) measurement range</td>
<td>0.1–2 ms</td>
</tr>
<tr>
<td>Input Pace signal amplitude range</td>
<td>8 mV–700 mV</td>
</tr>
<tr>
<td>Input Voltage (Vin)</td>
<td>5 V from Micro-USB</td>
</tr>
</tbody>
</table>
Test pacemaker detection with TIDA-010005 & TIDA-01614
Device Datasheets:

- **AFE4900**
- **CC2640R2F**
- **TPS61098**
- **TPS63036**
- **TPD1E10B06**

**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

**Benefits**

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

**Target applications**

- **Wireless patient monitor**
- **Pulse oximeter**
- **Wearable fitness & activity monitor**
- **ECG**

**Tools & resources**

- **Wearable, wireless, multiparameter patient monitor reference design**

---

**TIDA-01580**

Wearable, wireless, multiparameter patient monitor reference design
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)

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

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...

## TIDA-01624 Bluetooth-enabled high accuracy skin temperature measurement flex PCB patch

### Features
- High accuracy, low power temperature sensor
- BLE 4.2 and 5 enabled microcontroller
- Thin-film flexible battery power, enabling entirely flexible design
- Integrated PCB antenna
- Temperature updates every second

### Benefits
- Low power consumption and long battery life
- Extremely long shelf life (3+ Years)
- Small, flexible form factor
- Connects to smart device
- Zero-calibration to ±0.1°C accuracy

### Applications
- Medical sensor patches
- Multiparameter patient monitors
- Smart patches

### Tools & resources
- TIDA-01624 and/or tools folder
- Design guide
- Design files: Schematics, BOM, Gerbers, Software, etc.

### Device datasheets:
- TMP117
- CC2640R2F

### Diagram
- Skin Temperature TMP117
- BLE MCU CC2640R2F
- I2C
### Features

#### Accuracy
- 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

### 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

### Applications

- Gas meter
- Medical
- Cold chain
- Wearables
- Instrumentation & test
- Thermocouple – reference

---

**Table: Accuracy**

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

---

**Graph:**

- Average
- Class AA RTD
- TMP MinMax

---

**Images:**

- TMP117x Ultra-high accuracy digital temp sensor with integrated non-volatile memory
- Thermal pad with connections labeled SCL, SDA, GND, ALERT, V+, ADDX.
Full system: Multiparameter patient monitor + wireless sensors
### Why TI SimpleLink™ for multiparameter patient monitor + sensor patch?

<table>
<thead>
<tr>
<th>Low power</th>
<th>Ease of use</th>
<th>Secure</th>
<th>Small size</th>
</tr>
</thead>
</table>
| • BLE SoC with integrated ultra low power sensor controller  
• Wi-Fi low power IoT  
• Best-in-class standby current | • CC3135/CC3235 Wi-Fi modules  
• 5GHz Wi-Fi to reliably connect to hospital network  
• BLE multirole support, up to 32 simultaneous connections | • FIPS 140-Level 1 validation  
• Offload CPU bandwidth – HW crypto accelerators  
• Secure boot | • 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?
Achieve isolation and help enable 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/)

![Monitor with modules]

- ECG module
- SpO2 module
- CO2 module
- BP module
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>Option – 1: 3.3 V to 24 V from AC/DC power supply</td>
</tr>
<tr>
<td></td>
<td>Option – 2: From 15-42 V battery (6.7 V to 16 V)</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>Option – 1: 3.3 V or 5 V</td>
</tr>
<tr>
<td></td>
<td>Option – 2: 3.5 V or 5.5 V to be followed by an Low Drop-out Regulator (LDO)</td>
</tr>
<tr>
<td>Output power</td>
<td>Typical 5 watts to 7 watts</td>
</tr>
<tr>
<td>Isolation</td>
<td>5 kV and above</td>
</tr>
</tbody>
</table>

Programmable (typ. 3.5V/5V/12V @ 1A max)

5kV Isolation

5V/12V/18V
Or
2S/3S/4S (7.2V to 16.8V)
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**

- Simplified transformer design
- No optocouplers required
- Smaller size
- Total BoM = 21 components (including passives)
- Tight load regulation achieved

**Parameter** | **Value**
--- | ---
Input voltage (Vin) | 4.5V to 65V (70V max)
Output voltage (Vout) | Adjustable
Output power (Pout) | 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

**Conventional flyback**

- Tertiary feedback winding needed
- Optocoupler needed

**Suggested TI devices:**
LM5180
LM25180

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

Design Calculator
Design calculator for LM25180

LM25180 PSR Flyback Converter Design Tool

Step 1: Operating Specifications
- Input Voltage (Min, V_{Input}): 7 V
- Input Voltage (Max, V_{Input}): 12 V
- Input Voltage: 15 V
- 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: 2.5 μH
- Magnetizing Inductance, L_{M1}: 2.5 μH
- Primary Winding DCR: 100 mΩ
- Secondary Winding #1 DCR: 100 mΩ
- Secondary Winding #2 DCR: 100 mΩ
- Pin-sec Leakage Inductance: 200 nH
- Turns Ratio, PRI: SEC1: SEC2: 3:1
- Transformer SECS: 2:3
- Duty Cycle at V_{Input}: 62.5%
- Max Output Power at V_{Input}: 1.18 W

Step 3: Input & Output Capacitors
- Minimum Input Capacitance: 22 μF
- Input Capacitance, C_{IN}: 36 μF
- Input Capacitor ESR: 5 mΩ
- Resulting Input Voltage Ripple: 36 mV

- Minimum Output Capacitance, Output #1: 36.3 μF
- Output Capacitance, C_{OUT1}: 100 μF
- Output Capacitor ESR: 3 mΩ
- Resulting Output Voltage Ripple, Output #1: 35 mV

Step 4: Feedback, Soft-start, TC, UVLO
- Recommended Feedback Resistor: 10 kΩ
- Selected Feedback Resistor, R_{FB}: 8.7 kΩ
- Soft-Start Configuration: Adjustable
- Soft-Start Time: 18 ms
- Soft-Start Capacitance, C_{SS}: 47 μF
- VOUT Thresh Compensation: Adjustable
- % Same TC Pin Opens

- Input UVLO Configuration: Adjustable
- Input UVLO Turn-On Threshold: 4.6 V
- Input UVLO Turn-Off Threshold: 4.3 V
- Upper UVLO Resistor, R_{UVH}: 10 kΩ
- Lower UVLO Resistor, R_{UVL}: 5 kΩ

Diagram showing various electrical parameters and calculations for the LM25180 converter.
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

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

Suggested TI devices:
SN6505A
SN6505B
Isolated power module

Suggested TI device: UCC12050

UCC12050 schematic

Scalability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage (Vin)</td>
<td>4.5V to 5.5V</td>
</tr>
<tr>
<td>Output voltage (Vout)</td>
<td>Regulated 3.3V or 5V</td>
</tr>
<tr>
<td>Output power (Pout)</td>
<td>0.5 W</td>
</tr>
<tr>
<td>Isolation level</td>
<td>5kV RMS reinforced</td>
</tr>
<tr>
<td>Size</td>
<td>10.3mm x 7.5mm x 2.65mm</td>
</tr>
<tr>
<td>Output regulation</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

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.
Integrated transformer technology benefits

Discrete solution

UCC12050

Single chip solution (UCC12050) advantages:
- Smaller size and low profile
- Very low isolation capacitance Cps 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 ~30°C lower than air-core solution when operating at 5 V\textsubscript{IN}/5 V\textsubscript{OUT} 100 mA
ISOWatt – Isolated power and data

**ISOW7841 schematic**

**Integrated isolated power & data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage (Vin)</td>
<td>3V to 5.5V</td>
</tr>
<tr>
<td>Output voltage (Vout)</td>
<td>Regulated 3.3V or 5V</td>
</tr>
<tr>
<td>Output power (Pout)</td>
<td>0.65 W</td>
</tr>
<tr>
<td>Isolation level</td>
<td>5kV RMS reinforced</td>
</tr>
<tr>
<td>Size</td>
<td>10.3mm x 7.5mm x 2.65mm</td>
</tr>
<tr>
<td>Output regulation</td>
<td>1%</td>
</tr>
</tbody>
</table>

**Suggested TI device:** ISOW7841, ISOW7821

Radiated Emissions of the ISOW7841 vs a Competitive Device at 5-V Input and 80-mA Load

**Parameter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission level (dB)</td>
<td>41</td>
</tr>
</tbody>
</table>
Digital isolators – signal isolation

**Suggested TI device:**
ISO7741DW
ISO7841DWW

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ISO7741DW</th>
<th>ISO7841DWW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viso</td>
<td>5kVrms</td>
<td>5.7kVrms</td>
</tr>
<tr>
<td>Creepage/Clearance</td>
<td>8 mm</td>
<td>14 mm</td>
</tr>
<tr>
<td>Data rate</td>
<td>100 Mbps</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>IEC 60601-1 Capability</td>
<td>2 MOPP up to 240Vrms</td>
<td>2 MOPP up to 400Vrms</td>
</tr>
<tr>
<td>Size</td>
<td>10.3 x 7.5 mm</td>
<td>10.3 x 14.0 mm</td>
</tr>
</tbody>
</table>
Layout comparison – power and 4-ch data isolation

Digital isolator (ISO7741) is on bottom layer

\[ Z = 4.25\text{mm} \]

\[ Z = 6\text{mm} \]

\[ Z = 7.6\text{mm} \]
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional flyback (LM25180)</th>
<th>PSR flyback (SN6505)</th>
<th>Open-loop push-pull (LM25037)</th>
<th>Closed-loop push-pull (UCC12050)</th>
<th>Isolated power with digital isolator (ISOW7841)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output power level</strong></td>
<td>Flexible (transformer and PWM controller dependent)</td>
<td>5 W to 7 W</td>
<td>5 W</td>
<td>Flexible (transformer and PWM controller dependent)</td>
<td>0.5 W</td>
</tr>
<tr>
<td><strong>Input voltage range</strong></td>
<td>Up to 42V/65V</td>
<td>Up to 42V/65V</td>
<td>Up to 5.5V</td>
<td>Up to 75V</td>
<td>Up to 5.5V</td>
</tr>
<tr>
<td><strong>Output regulation</strong></td>
<td>1% or less</td>
<td>1%</td>
<td>5 to 10%</td>
<td>1% or less</td>
<td>1.5%</td>
</tr>
<tr>
<td><strong>No. of discrete components</strong></td>
<td>More than 30</td>
<td>21</td>
<td>10</td>
<td>46</td>
<td>Less than 10</td>
</tr>
<tr>
<td><strong>Isolation rating</strong></td>
<td>Flexible (transformer dependent)</td>
<td>Flexible (transformer dependent)</td>
<td>Flexible (transformer dependent)</td>
<td>Flexible (transformer dependent)</td>
<td>5000 Vrms reinforced</td>
</tr>
<tr>
<td><strong>Emission</strong></td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
Application report


---

**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.
Part number TLV32DAICM4EV4+H 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 Q5. 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...
IMPORTANT NOTICE AND DISCLAIMER

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

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

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

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2021, Texas Instruments Incorporated