Power Supply Subsystems for Vital Sign Monitors

Second Edition
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Introduction

This document offers descriptions of pre-validated power supply circuits for use with biosensing devices intended for wearable medical and healthcare applications. In addition, each power supply circuit example is complemented with a validation checklist and troubleshooting guide to aid circuit designers if needed.

All circuits have been designed, built, and tested to ensure the SNR performance of each Analog Devices biosensing AFE device (See the "How Power Supply Noise Affects Sensing Data" section).

Who Should Read This?

This guide is beneficial for engineers designing remote patient monitors and consumable diagnostic devices using Analog Devices vital sign monitoring AFEs.

Part Number	Function
MAX30001CWV+ MAX30003CWV+ MAX30004CWV+	ECG, R-to-R, Pace, and BioZ Biosensor Ultra-Low Power, Single-Channel Integrated Biopotential (ECG, R-to-R Detection) AFE Ultra-Low Power, Single-Channel Integrated Biopotential HR Detection AFE
MAX86140ENP+ MAX86141ENP+	Optical Pulse Oximeter and Heart Rate Biosensor (MAX86140 Single Channel; MAX86141 Dual Channel)
MAX86176ENX+	ECG, Optical Pulse Oximeter, and Heart Rate Biosensor
MAX86131CWA+	Electrochemical Biosensor
MAX30208CLB+	±0.1°C Accurate, I^2C Digital Temperature Sensor

How is This Applicable?

Retrieving actionable information from biosensor data requires excellent system signal-to-noise performance. Adopting Analog Devices analog front ends (AFE) is the first step towards this goal (Maxim Integrated mgineer Blog: Designing Accurate, Wearable Optical Heart Rate Monitors; August 2017; Easson, Craig). The next step should be complemented with a well-founded power supply design.

This cookbook:

- Guides engineers to select a power supply configuration based on system requirements
- Provides reference circuits and layouts of both discrete and integrated designs
- Presents a power supply performance test methodology to validate the system over different device use cases and transient loading conditions

- Presents a comprehensive checklist to validate the implementation
- Includes test data expected from a successful implementation to allow readers to assess their specific results
- Provides system integration guidelines
- Provides troubleshooting instructions to address implementation issues

Remote Patient Monitor and Medical Wearable System Configurations

This cookbook is applicable to designs with the following requirements:

- Proper power system architecture including a power/ground system design that isolates digital from analog domain circuits
- Very high signal-to-noise performance required at sampling rates below 1kHz
- Sufficient power supply decoupling and filtering to ensure biosensor performance
- Lab test validation of biosensing systems with extensive test conditions (e.g., overstress level testing, evaluation of “wake” and “sleep” mode changes, etc.)
- Small system form factor and low weight
- Maintain sufficient battery life with low battery weight and cost. Most of the systems are kept in standby or low power state
- Uses one or more (primary or secondary) batteries with nominal voltage ranging from 1.0V to 4.2V. For example:
  - *LP401230 3.7V 105mAh Secondary (Rechargeable) Cell LiPo Battery*
  - *CR2032 3.0V 235mAh Primary (Non-rechargeable) Cell Li Battery*
- Includes devices which require one or more voltage rails, for example
  - *1.8V for digital devices (V_{DIG}) with fast transitions and high operating current*
  - *1.8V analog supply (V_{ANA}) where power supply noise affects sensor data integrity*
  - *5V supply for LED currents (V_{LED}) in optical systems.*

Analog Devices’ rechargeable power system configuration is designed to work with input voltages ranging from 3.0V to 4.2V, typical of Li-Ion or LiPo rechargeable batteries. Three outputs are generated: two 1.8V supplies (V_{ANA} and V_{DIG}) and one 5V supply (V_{LED}). Figure 1 shows a block diagram for reference. One supply is a tightly regulated 1.8V digital supply to power the digital sections of a microcontroller where noise is typical with fast transitions of digital signals.

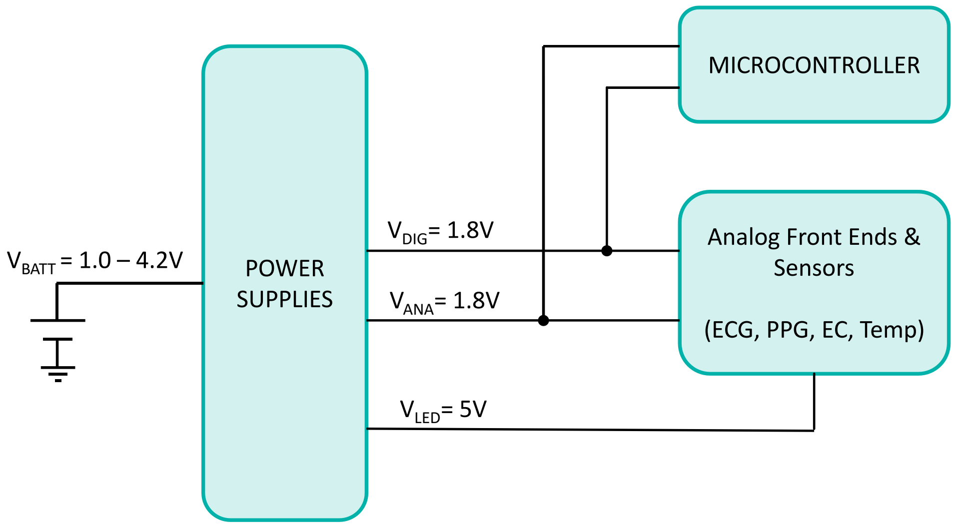

Figure 1. Typical Power Supply Configuration

How Power Supply Noise Affects Biosensing Data

Switching power supplies (a.k.a. DC-DC Converters) generate high frequency noise (ripple and switching spikes) that can be aliased in-band when vital sign signals are sampled at lower frequencies by the AFE ((Mathuranathan, 2011, p. 3) ref). To avoid performance degradation of wearable medical/healthcare systems, this noise requires mitigation. Key vital sign features for advanced applications involve very weak (i.e., small) signals, often requiring 100dB or better signal-to-noise ratio (SNR).

Mitigating this signal-to-noise degradation can involve many design techniques applied to system architecture, circuit, and layout design. This cookbook provides all design and validation considerations for each recommended configuration.

Battery Choices for Wearable Applications

Common wearable battery types can be categorized into two basic groups: primary cell (non-rechargeable) and secondary cell (rechargeable) batteries. Examples of primary cell batteries include alkaline, Li-ion, zinc-air, and silver-oxide varieties and secondary cell battery examples include Li-ion and lithium polymer (LiPo or LiPoly) cells. Currently, Lithium Ion and Lithium Polymer batteries are preferred for wearable applications due to their size, weight, rechargeability, energy density, and eco-friendliness.

The designer should be aware that each battery type has its own electrical characteristics (e.g., voltage output level, energy storage level, charge/discharge behavior, etc.), thus an appropriate switch-mode power supply (SMPS) circuit needs to be implemented. In addition, as newer battery types are deployed, the designer needs to evaluate, characterize, and possibly redesign their power supply circuits accordingly.

The DC-DC converter circuits (a.k.a. Switch-Mode Power Supplies or SMPS) presented in this document identify all battery types used.

Switch-Mode Power Supply Circuits

The following sections highlight operational details of known good reference designs including:

- Circuit description including web links to applicable design files (schematic/BOM/layout)
- Validation checklist to confirm the implemented circuit function
- Select test data plots highlighting typical operating characteristics
- Troubleshooting Instructions

Both discrete and integrated switch-mode power supply options are offered to help designers accommodate their specific PCB layout requirements.

Analog 1.8V SMPS Circuit Using the MAX38640A (Buck) Device

The following MAX38640A circuit (Figure 2) illustrates typical input and output power supply levels for a properly operating Switch-Mode Power Supply (SMPS) device in wearable medical/healthcare applications. As shown in Figure 2, digital multimeters (DMM) can be used to probe the input and output ports to validate the supply voltage levels. Note that power supply output levels can vary due to various factors such as:

- Battery discharge
- Changing loads (e.g., device mode changes, devices waking up from sleep mode, etc.)

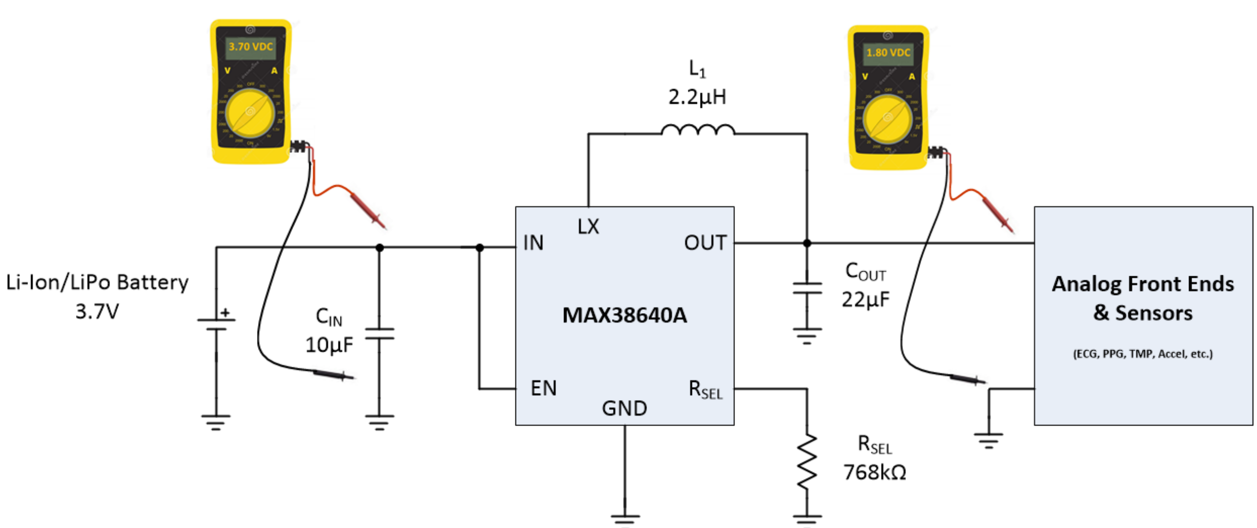

Figure 2. Analog 1.8VDC MAX38640A SMPS Circuit for Wearable/Healthcare Applications

The following link can be used to obtain the MAX38640A circuit reference design files.

Design File Type	Name	Format	Link
Schematic	MAX38640A_MPS_cookbook_Apps_P1_Schematic	Multiple	Reference Design Resources
Bill of Materials	Build_BOM_MAX38640A_MPS_cookbook_Apps_P1	Excel	
Layout	MAX38640A_MPS_cookbook_Apps_P1_ODB++.tgz	Multiple	

Analog 1.8V SMPS Circuit Validation Checklist

The following table can be used as a checklist to validate the operation of the analog 1.8V SMPS circuit using the MAX38640A device while connected to a load.

Step	Action	Procedure	Measurement	Need Help?
1	Check input DC power supply	Measure voltage across battery	Reading range: 2.8V to 4.2V	Troubleshooting Instructions
2		Measure voltage across C_{IN}	Reading range: 2.8V to 4.2V	
3	Check V_{OUT} DC level	Measure voltage across C_{OUT}	Reading range: 1.71V to 1.89V	
4		Measure voltage across load	Reading range: 1.71V to 1.89V	
5	Check Output Noise Level	*Use differential oscilloscope probe method across C_{OUT}	Ripple Noise level should be <20mV$_{PP}$	

Typical Operating Characteristics

The following figures highlight the typical operating characteristics of the MAX38640A circuit under various load conditions. The test equipment used includes:

- Input Power Supply Source: B&K Precision BK1718 DC power supply
- Electronic Load: MAXREFDES1213 Smart Load using the MAX32630FTHR and MAX11311
- Benchtop DMM: B&K Precision BK2831E True RMS Bench digital multimeter

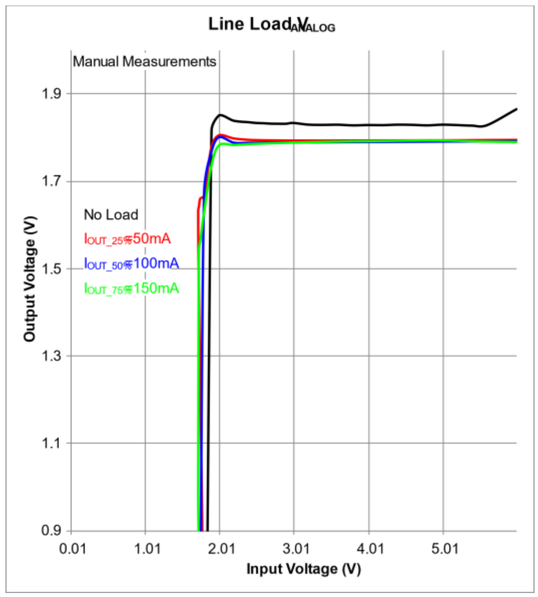

Figure 3. Line Load for Analog 1.8V MAX38640A SMPS Circuit

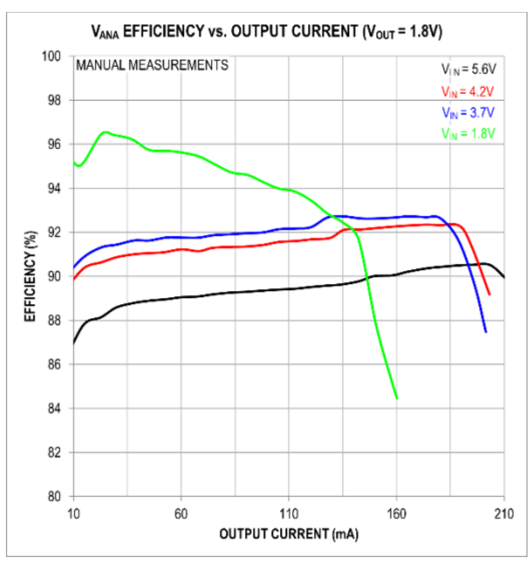

Figure 4. Efficiency of Analog 1.8V MAX38640A SMPS Circuit

Typical Operating Characteristics

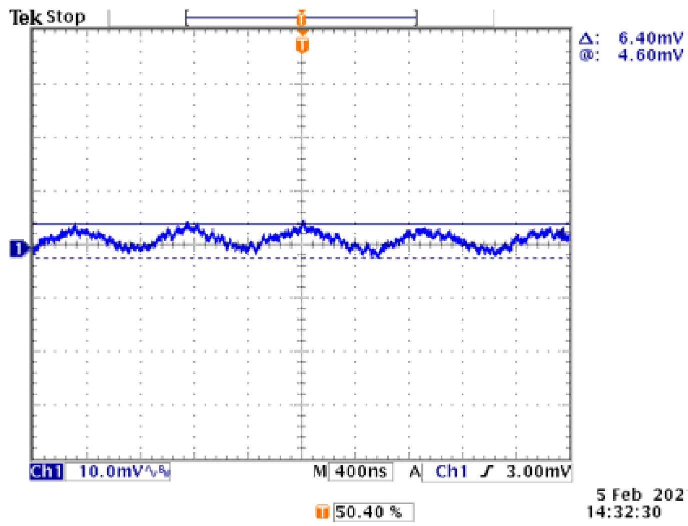

Figure 5. Typical Output Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

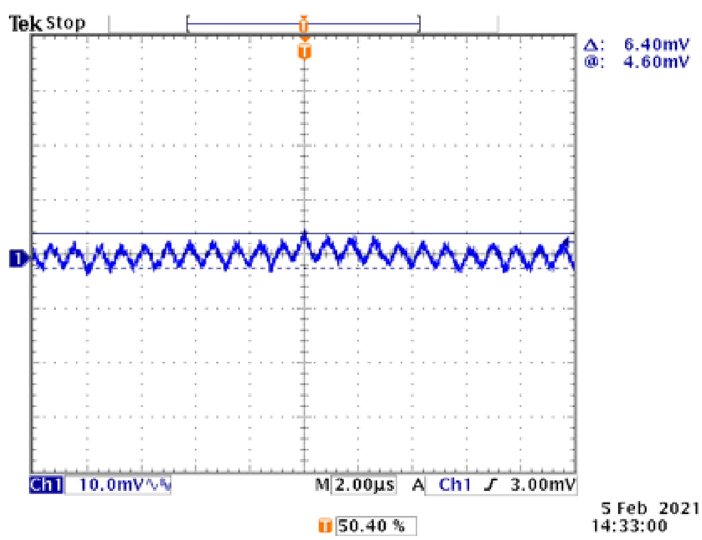

Figure 6. Typical Output Ripple Voltage (V_{IN} = 4.2VDC, I_S = 100mA)

Troubleshooting the MAX38640A (Analog 1.8V Output) SMPS Circuit

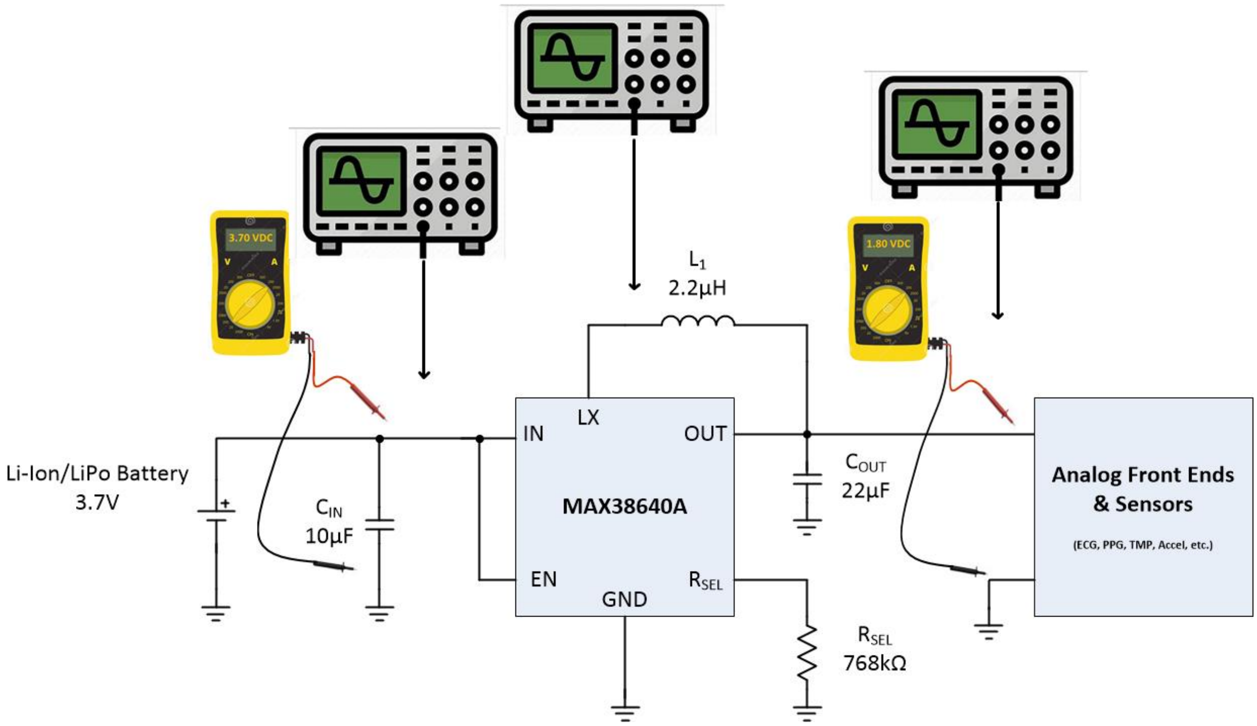

Figure 7. Troubleshooting the MAX38640A SMPS Circuit

Troubleshooting the MAX38640A SMPS Circuit:

Step 1. Check the Input Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage at the input to the MAX38640A device. Be sure to connect the negative black lead to ground and the positive red lead to the input "IN" pin of the device. If the input pin is not easily assessable, place the leads across the input capacitor, C_{IN}.

Use the following table to diagnose and fix associated problems.

Input Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	Battery uncharged or defective	Disconnect battery and check voltage; if it reads 0V, recharge battery	Replace battery if it does not charge
	No connection from battery (IN or GND line)	Disconnect battery and test for conductivity from battery connector to device input	PCB may have an open

	Input capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	Bad capacitor, PCB may have short
	EN pin connected to ground	Disconnect battery and test for conductivity from EN pin to ground	EN pin needs to be tied high for normal operation
Reading < 2.8V	Low battery charge Battery defective	Disconnect battery and check voltage; if it reads below 2.8V, recharge battery	Replace battery if it does not charge
2.8V ≥ Reading ≤ 4.2V		No action	Input voltage OK, proceed to step 2
Reading ≥ 4.2V	Defective battery	Replace battery	

Step 2. Check the Inductor Signal Waveform: Using an oscilloscope or digital storage scope (DSO), probe the LX pin on the MAX38640A device. If the input pin is not easily assessable, place the probe on the inductor end cap.

If the circuit is operating correcting with a light load (i.e., less than 50mA), the waveform should appear as shown in the following figure.

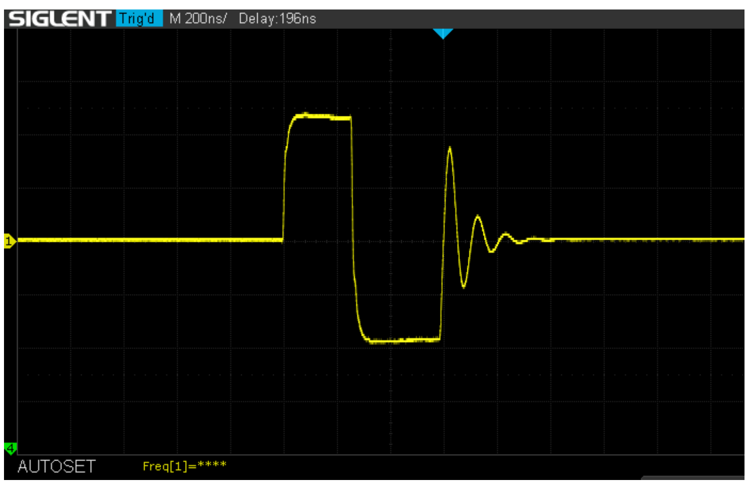

Figure 8. Typical MAX38640A VLX Waveform with Light Load

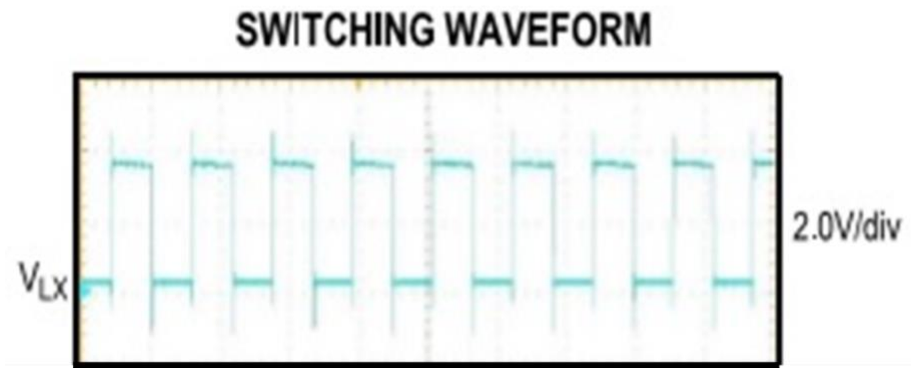

Figure 9. Typical MAX38640A VLX Waveform

The square wave amplitude should be approximately equal to the input battery voltage. The square wave floor voltage should be about 200mV to 300mV below ground (e.g., -250mV). The duty cycle is proportional to the output voltage, thus a 3.6V input battery voltage has an approximate 50% duty cycle when producing an output voltage of 1.8V. Figure 10 shows the relationship between the duty cycle and output voltage.

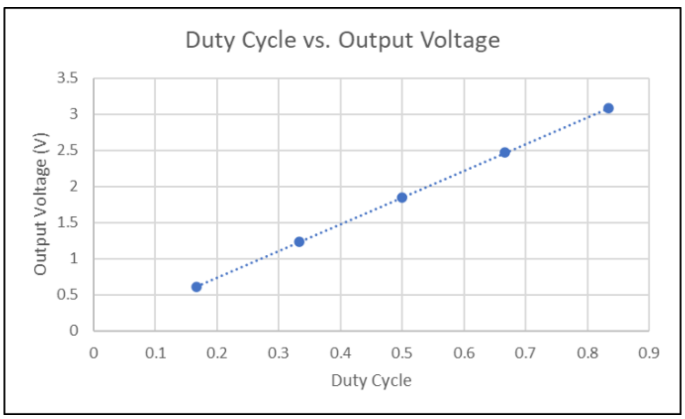

Figure 10. MAX38640A Duty Cycle Versus Output Voltage

Deviations from the ideal square wave can be used to effectively diagnose and fix many problems.

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Amplitude is not correct	Inductor open IN pin open EN is open or ground	Disconnect battery and check all connections with DMM	Repair PCB if needed
Duty Cycle is not correct (Does not correlate to the output voltage)	R_{SEL} is not the correct value (768kΩ), bad external resistor.	Disconnect battery and check R_{SEL} with a DMM (R-measurement)	Replace resistor with correct value resistor
	R_{SEL} pin open (V_O = 2.5V)	Check output for 2.5V Disconnect battery and test for conductivity from resistor to R_{SEL} pin	PCB may have an open
	R_{SEL} pin shorted to ground (V_O = 0.8V)	Check output for 0.8V Disconnect battery and measure resistance across capacitor.	PCB may have short
Waveform distortion Rounded rising edge	Bad inductor connection	Re-connect inductor Replace inductor	Bad connection can cause higher line resistance

Step 3A. Check the Output DC Voltage: Using a digital multimeter (DMM) with an internal impedance of 1MΩ or larger (e.g., Fluke 87), measure the voltage at the output of the MAX38640A device. Be sure to connect the negative black lead to ground and the positive red lead to the output “OUT” pin of the device. If the output pin is not easily assessable, place the leads across the output capacitor, C_{OUT}.

Use the following table to diagnose and fix associated problems

Output Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	No connection from SMPS to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
Reading too low (<1.71VDC)	Inductor wrong value Inductor saturated R_{SEL} has wrong value	Disconnect battery and check for inductor and/or resistor values	
1.71V ≥ Reading ≤ 1.89V		No action	Operational
Reading too high (>1.89VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Step 3B. Check the Output AC Voltage: Using an oscilloscope or digital storage scope (DSO), we will now measure the output ripple (AC) by probing the OUT pin on the MAX38640A device. To measure the output and avoid RF pickup, it is recommended to use a differential probe technique.

If the circuit is operating correctly, the waveform should be a 1.8VDC output with a small ripple waveform superimposed on it. The ripple waveform should resemble that shown in the following figure:

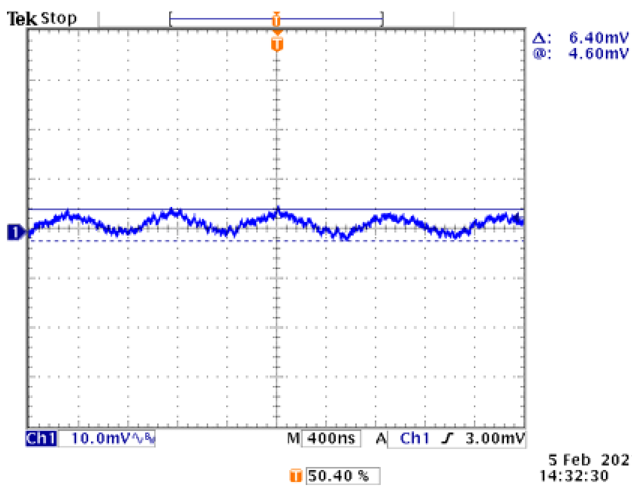

Figure 11. MAX38640A Output Ripple Waveform

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high (>$20mV_{PP}$)	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Ripple frequency does not match V_{LX} square wave frequency	Light load	Check load	
Broadband noise is too high	Load too large, environmental noise.	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition spikes too high (>$30mV_P$)	Load inductance, input current not adequate	Check line inductance, check input current with scope	

Digital 1.8V SMPS Circuit Using the MAX38640A (Buck) Device

The following MAX38640A circuits (Figure 12) illustrate typical input and output power supply levels for a properly operating Switch-Mode Power Supply (SMPS) device in wearable medical/healthcare applications. As shown in Figure 12, digital multimeters (DMM) can be used to probe the input and output ports to validate the supply voltage levels. Note that power supply output levels can vary due to various factors such as:

- Discharging battery
- Changing loads (e.g., device mode changes, devices waking up from sleep mode, etc.)

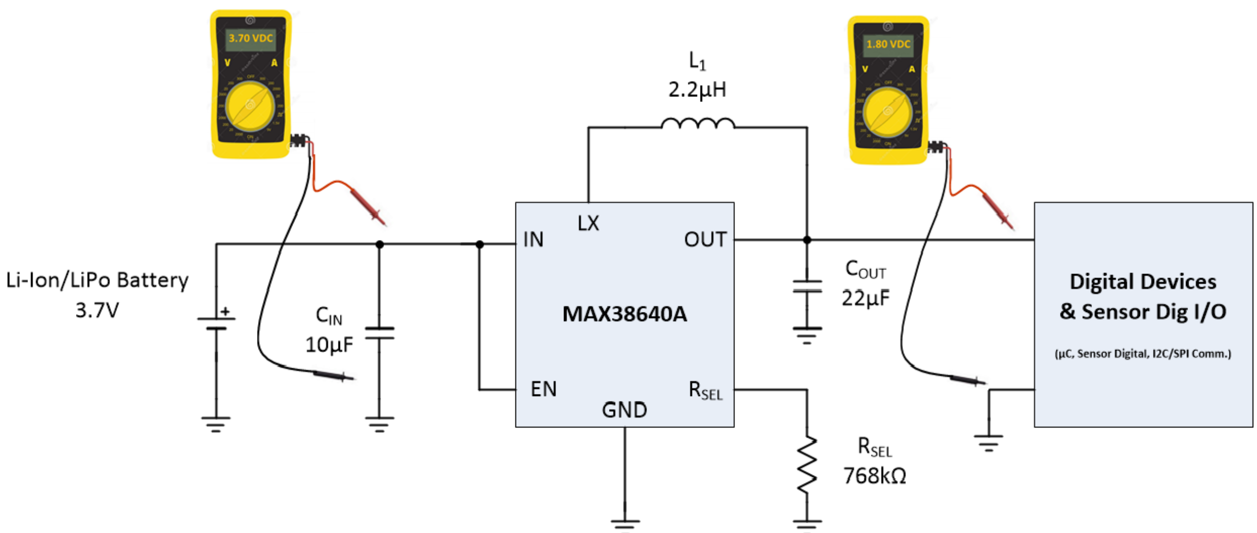

Figure 12. Digital 1.8VDC MAX38640A SMPS Circuit for Wearable Medical/Healthcare Applications

The following link can be used to obtain the MAX38640A circuit reference design files.

Design File Type	Name	Format	Link
Schematic	MAX38640A_MPS_cookbook_Apps_P1_Schematic	Multiple	Reference Design Files
Bill of Materials	Build_BOM_MAX38640A_MPS_cookbook_Apps_P1	Excel	
Layout	MAX38640A_MPS_cookbook_Apps_P1_ODB++.tgz	Multiple	

Digital 1.8V SMPS Circuit Validation Checklist

The following table can be used as a checklist to validate the operation of the digital 1.8V SMPS circuit using the MAX38640A device while connected to a load.

Step	Action	Procedure	Measurement	Need help?
1	Check input DC power supply	Measure voltage across battery	Reading range: 2.8V to 4.2V	Troubleshooting Instructions
2		Measure voltage across C_{IN}	Reading range: 2.8V to 4.2V	
3	Check V_{OUT} DC level	Measure voltage across C_{OUT}	Reading range: 1.71V to 1.89V	
4		Measure voltage across load	Reading range: 1.71V to 1.89V	
5	Check Output Noise Level	*Use differential oscilloscope probe method across C_{OUT}	Ripple Noise level should be $<20mV_{PP}$	

Typical Operating Characteristics

The following figures highlight the typical operating characteristics of the MAX38640A circuit under various load conditions. The test equipment used includes:

- Input Power Supply Source: B&K Precision BK1718 DC power supply
- Electronic Load: MAXREFDES1213 Smart Load using the MAX32630FTHR and MAX11311
- Benchtop DMM: B&K Precision BK2831E True RMS Bench digital multimeter

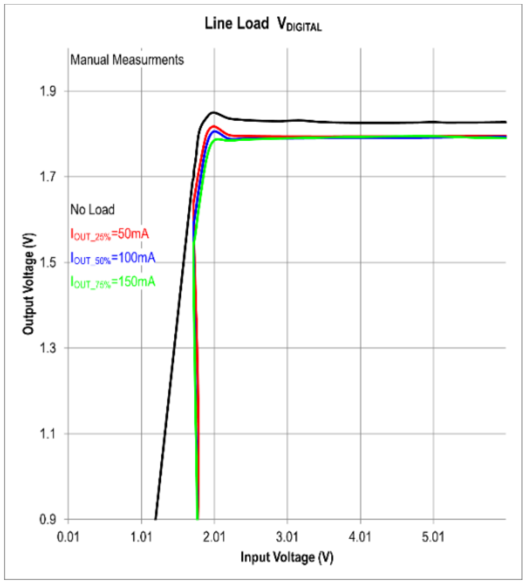

Figure 13. Line Load for the Digital MAX38640A SMPS Circuit

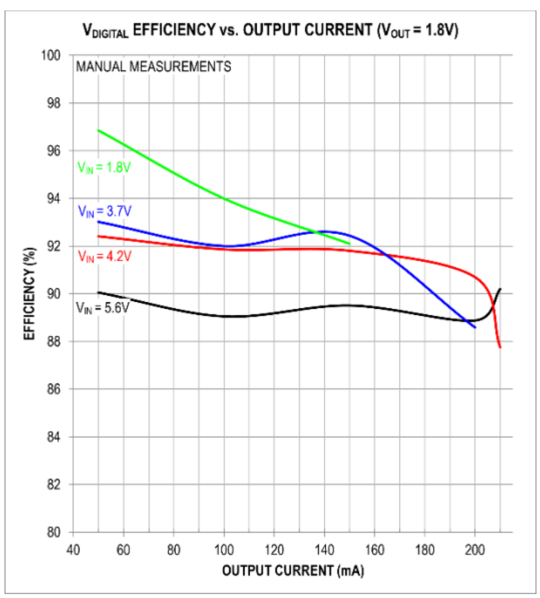

Figure 14. Efficiency of the Digital 1.8V MAX38640A SMPS Circuit

Typical Operating Characteristics

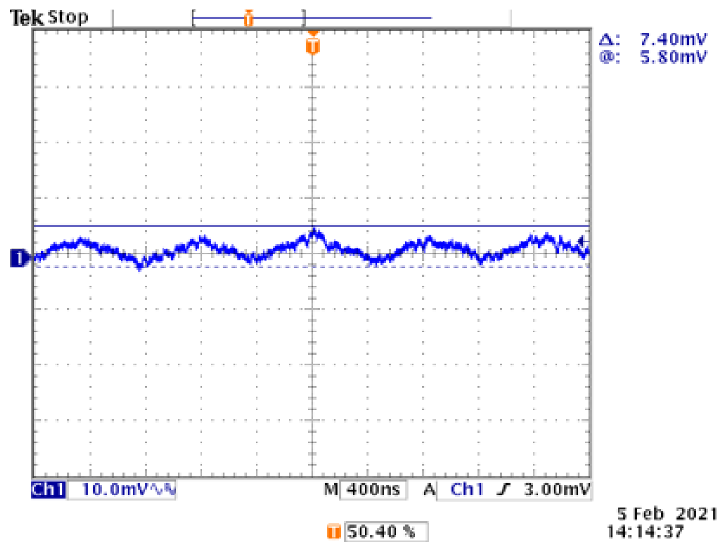

Figure 15. Typical Output Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

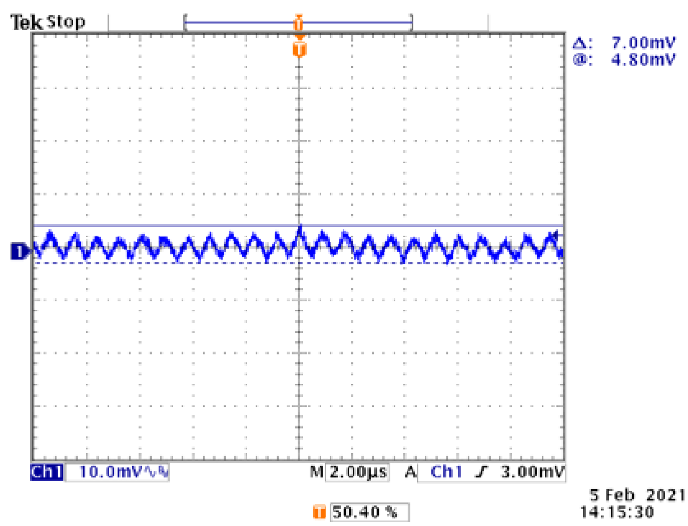

Figure 16: Typical Output Ripple Voltage (V_{IN} = 4.2VDC, I_S = 100mA)

Troubleshooting the MAX38640A (Digital 1.8V Output) SMPS Circuit

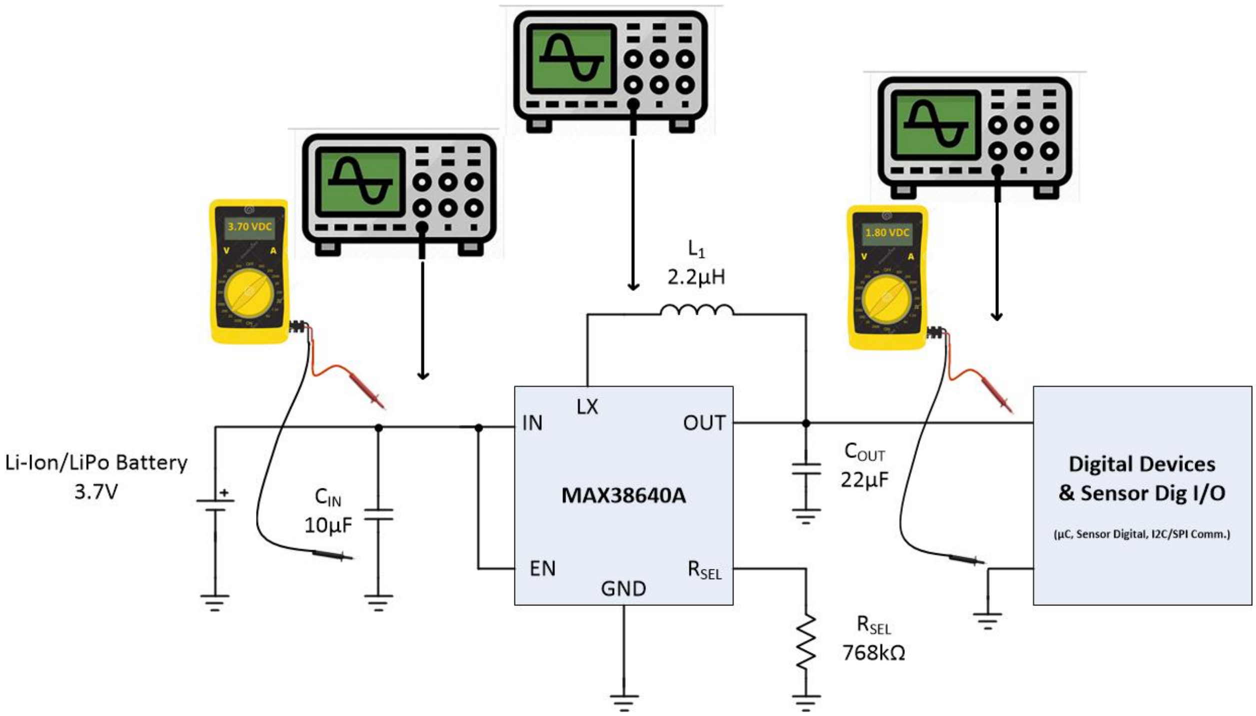

Figure 17. Troubleshooting the MAX38640A SMPS Circuit

Troubleshooting the MAX38640A SMPS Circuit:

Step 1. Check the Input Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage across at the input to the MAX38640A device. Be sure to connect the negative black lead to ground and the positive red lead to the input "IN" pin of the device. If the input pin is not easily assessable, place the leads across the input capacitor, C_{IN}.

Use the following table to diagnose and fix associated problems.

Input Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	Battery uncharged or defective	Disconnect battery and check voltage; if it reads 0V, recharge battery	Replace battery if it does not charge
	No connection from battery (IN or GND line)	Disconnect battery and test for conductivity from battery connector to device input	PCB may have an open

	Input capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	Bad capacitor, PCB may have short
	EN pin connected to ground	Disconnect battery and test for conductivity from EN pin to ground	EN pin needs to be tied high for normal operation
Reading < 2.8V	Low battery charge Battery defective	Disconnect battery and check voltage; if it reads below 2.8V, recharge battery	Replace battery if it does not charge
2.8V ≥ Reading ≤ 4.2V		No action	Input voltage OK, proceed to step 2
Reading ≥ 4.2V	Defective battery	Replace battery	

Step 2. Check the Inductor Signal Waveform: Using an oscilloscope or digital storage scope (DSO), probe the LX pin on the MAX38640A device. If the input pin is not easily assessable, place the probe on the inductor end cap.

If the circuit is operating correcting with a light load (i.e., less than 50mA), the waveform should appear as shown in the following figure.

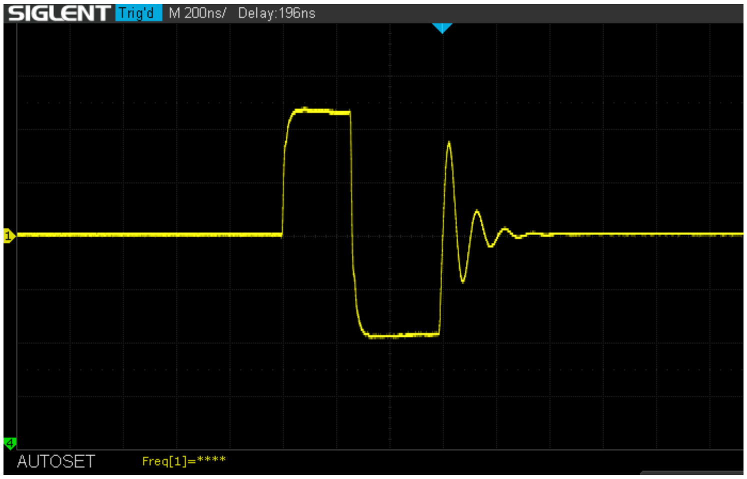

Figure 18. Typical MAX38640A VLX Waveform with Light Load

If the circuit is operating correcting with a heavy load, the waveform should be a square wave with minimal ringing on the rise and falling edges as shown in the following figure.

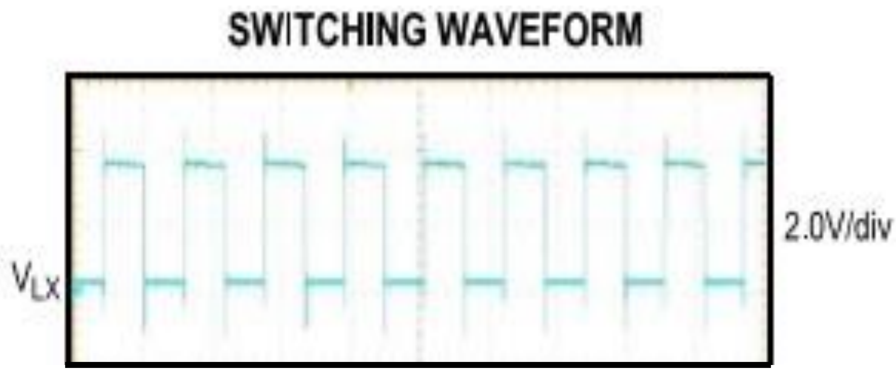

Figure 19. Typical MAX38640A VLX Waveform

The square wave amplitude should be approximately equal to the input battery voltage. The square wave floor voltage should be about 200mV to 300mV below ground (e.g., -250mV). The duty cycle is proportional to the output voltage, thus a 3.6V input battery voltage has an approximate 50% duty cycle when producing an output voltage of 1.8V. Figure 20 shows the relationship between the duty cycle and output voltage.

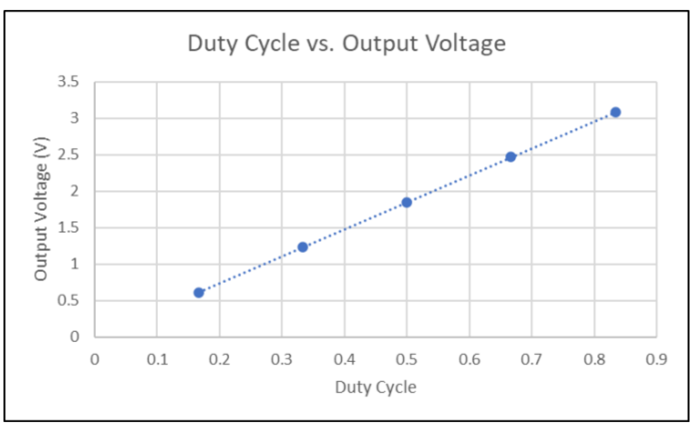

Figure 20. MAX38640A Duty Cycle Versus Output Voltage

Deviations from the ideal square wave can be used to effectively diagnose and fix many problems.

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Amplitude is not correct	Inductor open IN pin open EN is open or ground	Disconnect battery and check all connections with DMM.	Repair PCB if needed
Duty Cycle is not correct (Does not correlate to the output voltage)	R_{SEL} is not the correct value (768kΩ), bad external resistor	Disconnect battery and check R_{SEL} with a DMM (R-measurement)	Replace resistor with correct value resistor
	R_{SEL} pin open (V_O = 2.5V)	Check output for 2.5V, disconnect battery and test for conductivity from resistor to R_{SEL} pin	PCB may have an open
	R_{SEL} pin shorted to ground (V_O = 0.8V)	Check output for 0.8V, disconnect battery and measure resistance across capacitor	PCB may have short
Waveform distortion Rounded rising edge	Bad inductor connection	Reconnect inductor Replace inductor	Bad connection can cause higher line resistance

Step 3A. Check the Output DC Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage at the output of the MAX38640A device. Be sure to connect the negative black lead to ground and the positive red lead to the output "OUT" pin of the device. If the output pin is not easily assessable, place the leads across the output capacitor, C_{OUT}.

Use the following table to diagnose and fix associated problems.

Output Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	No connection from SMPS to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
Reading too low (<1.71VDC)	Inductor wrong value Inductor saturated R_{SEL} has wrong value	Disconnect battery and check for inductor and/or resistor values	
1.71V ≥ Reading ≤ 1.89V		No action	Operational
Reading too high (>1.89VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Step 3B. Check the Output AC Voltage: Using an oscilloscope or digital storage scope (DSO), we will now measure the output ripple (AC) by probing the OUT pin on the MAX38640A device. To measure the output and avoid RF pickup, it is recommended to use a differential probe technique.

If the circuit is operating correctly, the waveform should be a 1.8VDC output with a small ripple waveform superimposed on it. The ripple waveform should resemble that shown in the following figure.

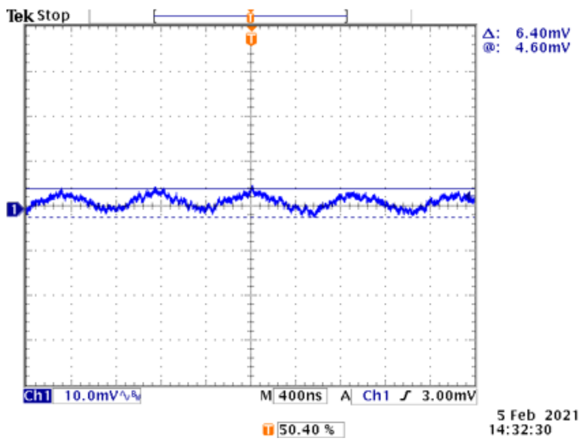

Figure 21. MAX38640A Output Ripple Waveform

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high (>20mV$_{PP}$)	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Ripple frequency does not match V_{LX} square wave frequency	Light load	Check load	
Broadband Noise is too high	Load too large, environmental noise	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition spikes too high (>30mV$_P$)	Load inductance, input current not adequate	Check line inductance, check input current with scope	

Digital 1.8V SMPS Circuit Using the MAX17220 (Boost) Device

The following MAX17220 circuit (Figure 12) illustrate typical input and output power supply levels for a properly operating Switch-Mode Power Supply (SMPS) device in wearable medical/healthcare applications. As shown in Figure 22, digital multimeters (DMM) can be used to probe the input and output ports to validate the supply voltage levels. Note that power supply output levels can vary due to various factors such as:

- Discharging battery
- Changing loads (e.g., device mode changes, devices waking up from sleep mode, etc.)

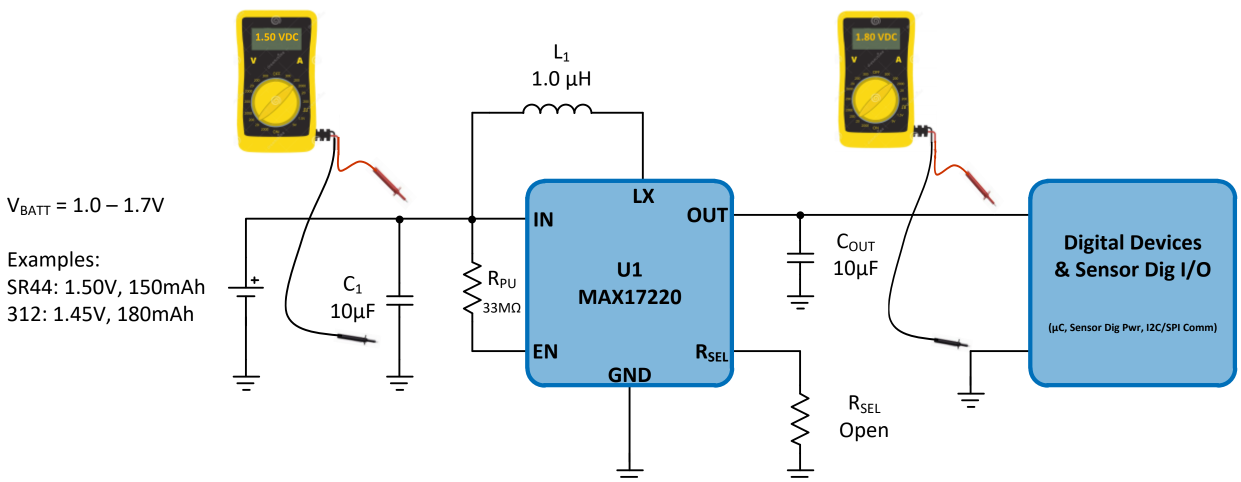

Figure 22. Digital 1.8VDC MAX17220 SMPS Circuit for Wearable Medical/Healthcare Applications

The following link can be used to obtain the MAX17220 PS Module circuit reference design files.

Design File Type	Name	Format	Link
Schematic	Cookbook_MAX17220_DB_Apps_P1_Schematic	Multiple	Reference Design Files
Bill of Materials	Build_BOM_Cookbook_MAX17220_DB_Apps_P1	Excel	
Layout	Cookbook_MAX17220_DB_Apps_P1_ODB++.tgz	Multiple	

Digital 1.8V SMPS Circuit Validation Checklist

The following table can be used as a checklist to validate operation of the digital 1.8V SMPS circuit using the MAX17220 device while connected to a biosensing circuit load.

Step	Action	Procedure	Measurement	Need Help?
1	Check input DC power supply SR44: Ag Oxide Batt 312: Zinc Air Batt	Measure voltage across Battery	Reading range: 1.2V – 1.6V 1.3V – 1.7V	Troubleshooting Instructions
2	Check input DC power supply SR44: Ag Oxide Batt 312: Zinc Air Batt	Measure voltage across C_1	Reading range: 1.2V – 1.6V 1.3V – 1.7V	
3	Check Vout DC level	Measure voltage across C_{OUT}	Reading range: 1.71V – 1.89V	
4		Measure voltage across load	Reading range: 1.71V – 1.89V	
5	Check Output Noise Level	*Use differential oscilloscope probe method across Cout	Ripple Noise level should be < 30mVpp	

Typical Operating Characteristics

The following figures highlight the typical operating characteristics of the MAX17220 circuit under various load conditions. The test equipment used includes:

- Input Power Supply Source: B&K Precision BK1718 DC power supply
- Electronic Load: MAXREFDES1213 Smart Load using the MAX32630FTHR and MAX11311
- Benchtop DMM: B&K Precision BK2831E True RMS Bench digital multimeter

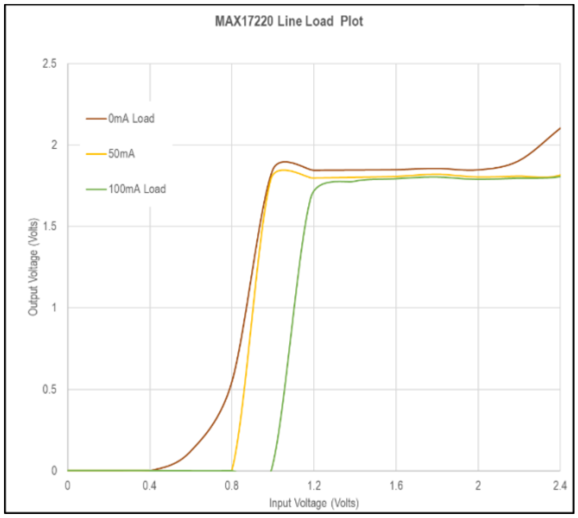

Figure 23. Line Load for the Digital MAX17220 SMPS Circuit

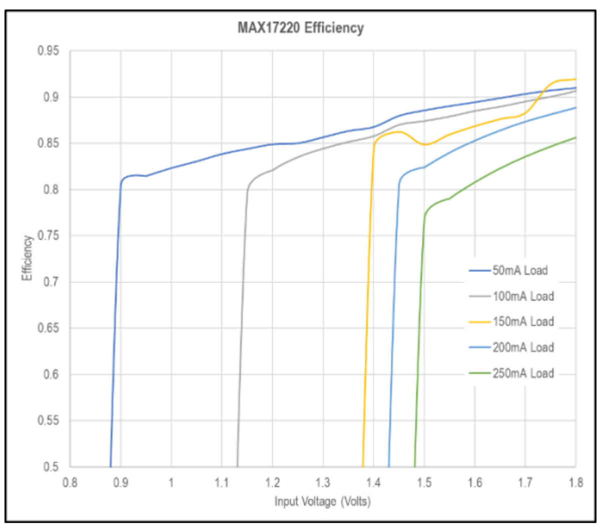

Figure 24. Efficiency of the Digital 1.8V MAX17220 SMPS Circuit

Typical Operating Characteristics

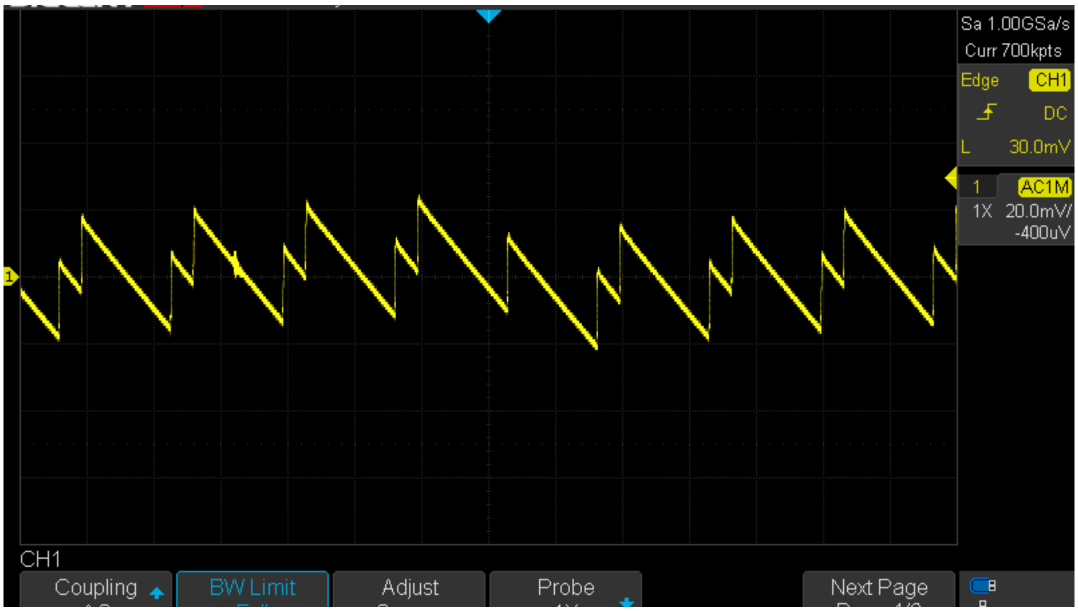

Figure 25. Typical Output Ripple Characteristic (V_{IN} = 1.5VDC, I_S = 2mA)

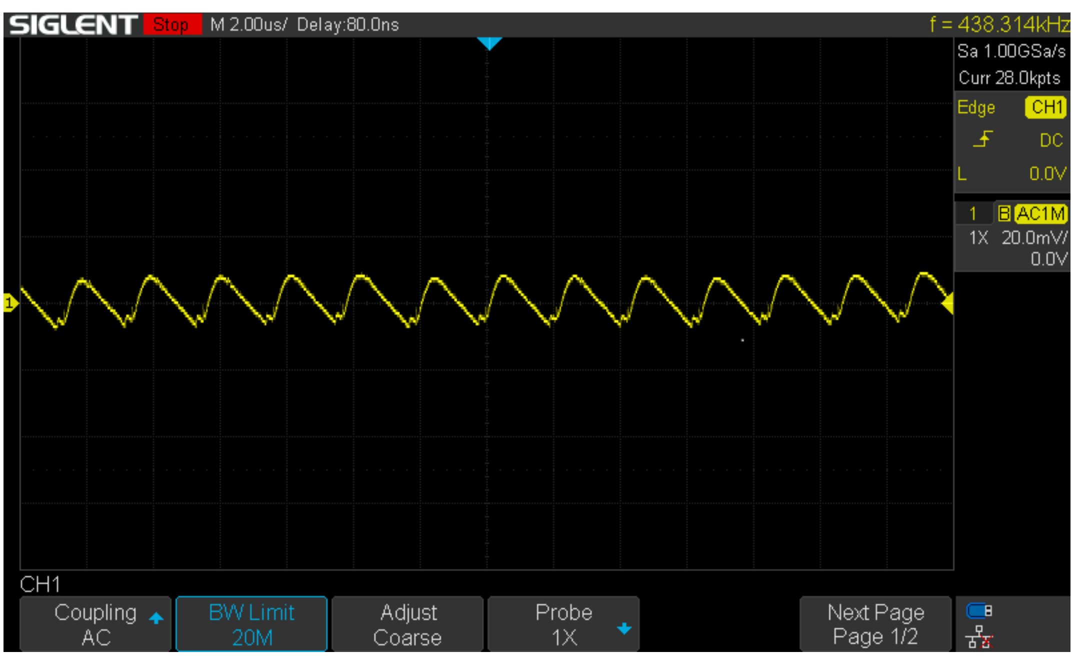

Figure 26: Typical Output Ripple Voltage (V_{IN} = 1.5VVDC, I_S = 45mA)

Troubleshooting the MAX17220 (Digital 1.8V Output) SMPS Circuit

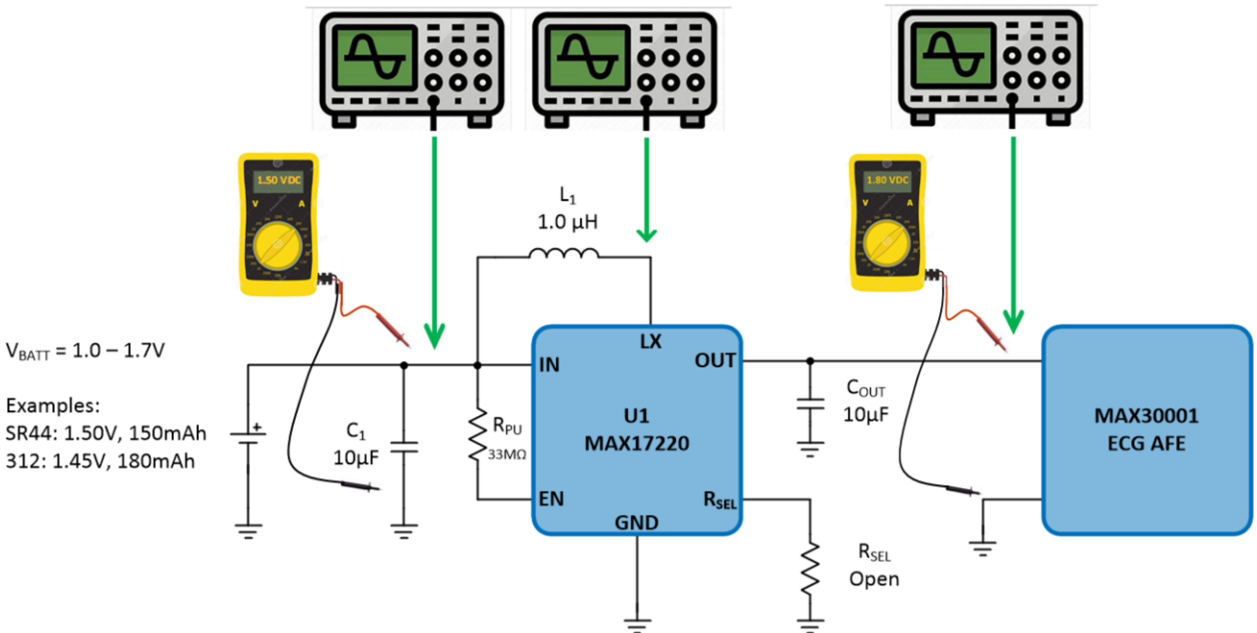

Figure 27: Troubleshooting the MAX17220 SMPS Circuit

<u>Troubleshooting the MAX17220 SMPS Circuit:</u>

Step 1 – Check the Input Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1Mohm or larger (e.g., Fluke 87), measure the voltage across at the input to the MAX17220 device. Be sure to connect the negative "black" lead to ground and the positive "red" lead to the input "IN" pin of the device. If the input pin is not easily assessable, place the leads across the input capacitor, C_1.

Use the following table to diagnose and fix associated problems:

Input Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	Battery uncharged. Battery defective.	Disconnect battery and check voltage. If it reads 0V, recharge battery.	Replace battery if it doesn't charge.
	No connection from battery (IN or GND line)	Disconnect battery and test for conductivity from battery connector to device input.	PCB may have an open.
	Input capacitor shorted to ground	Disconnect battery and check for continuity across capacitor.	Bad capacitor. PCB may have short.

	EN pin connected to ground	Disconnect battery and test for conductivity from EN pin to ground.	EN pin needs to be tied high for normal operation.
Zinc Air Battery: Reading < 1.2V Ag Oxide Battery: Reading < 1.3V	Low battery charge Battery defective	Disconnect battery and check voltage. If it reads below min V-Level, replace battery.	
Zinc Air Battery: 1.2V ≥ Reading ≤ 1.7V Ag Oxide Battery: 1.3V ≥ Reading ≤ 1.6V		No action.	Input voltage OK, proceed to step 2.
Zinc Air Battery: Reading ≥ 1.7V Ag Oxide Battery: Reading ≥ 1.6V	Defective battery	Replace battery and retest.	

Step 2 – Check the Inductor Signal Waveform: Using an oscilloscope or digital storage scope (DSO), probe the LX pin on the MAX17220 device. If the input pin is not easily assessable, place the probe on the inductor end cap.

If the circuit is operating correcting with a light load the waveform should appear as shown in the following figure:

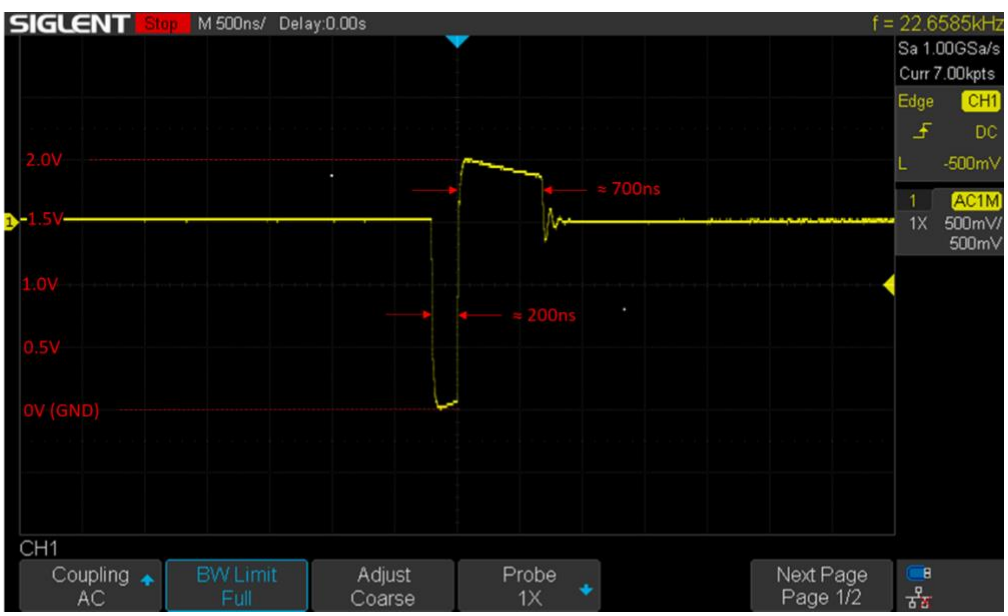

Figure 28: Typical MAX17220 V_{LX} Waveform with 2mA Load

As the MAX17220 employs pulse-frequency-modulation (PFM), the circuit will operate at higher repetition rates (i.e., higher frequency) under heavier loads with similar V_{LX} pulse waveforms. The figure below demonstrates this with a 45mA current load:

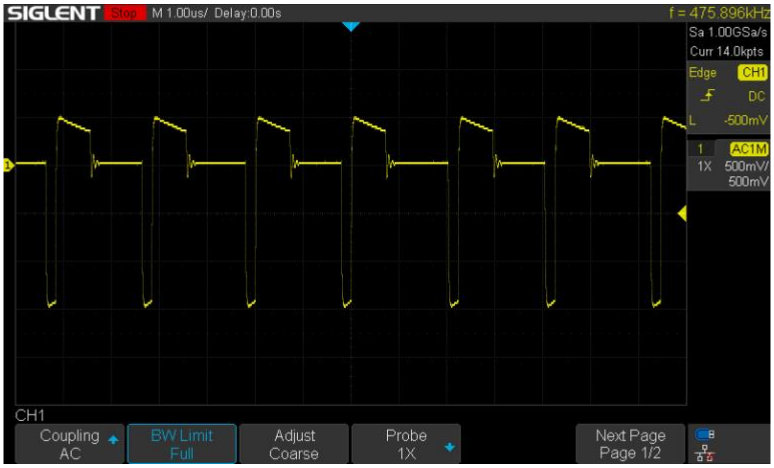

Figure 29: Typical MAX17220 V_{LX} Waveform with 45mA Load.

The typical V_{LX} peak-to-peak pulse amplitude should be approximately 2V. The frequency is proportional to the output load current. The figure below shows the relationship between the typical V_{LX} waveform frequency and output load current.

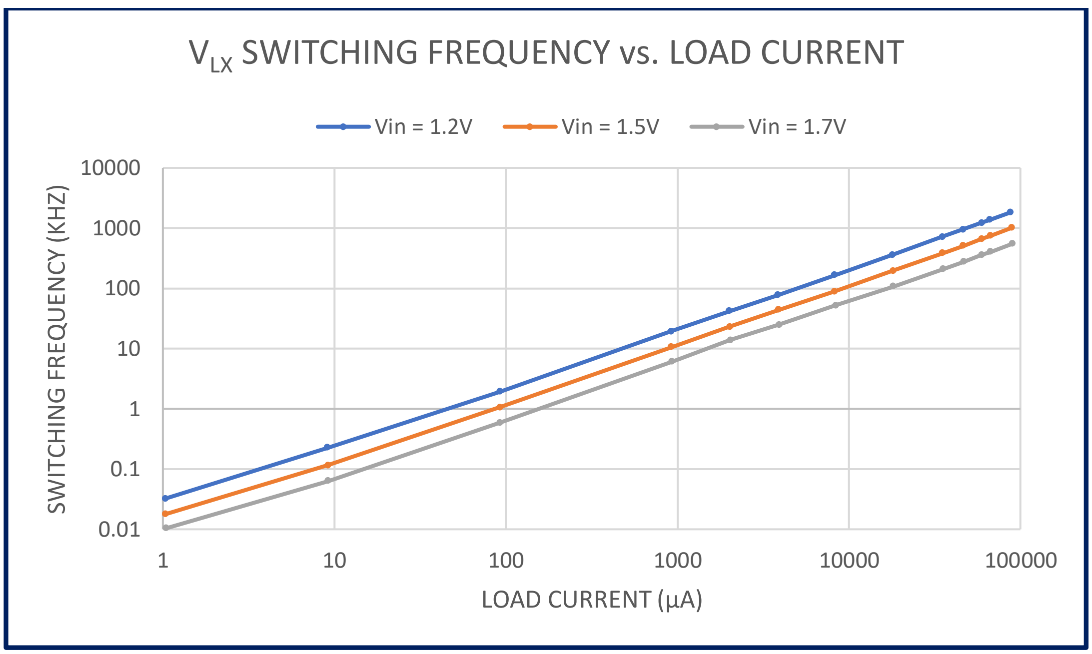

Figure 30: MAX17220 V_{LX} Frequency vs. Load Current

Deviations from the frequency and/or pulse waveform shape can be used to effectively diagnose and fix many problems.

Use the following table to diagnose and fix associated problems:

Input Waveform	Potential Cause	Action	Notes
No pulses	Inductor open. C_{OUT} is open IN pin open	Disconnect battery and check all connections with DMM.	Repair PCB if needed.
Pulse amplitudes (Neg & Pos Pulses) are not correct	Inductor wrong value Inductor saturated C_{OUT} value is too low	Disconnect battery and check for inductor and output capacitor values.	Replace components as needed.
Frequency is not correct (Doesn't correlate to the output load)	Inductor wrong value Inductor saturated C_{OUT} value is too low R_{SEL} is not open	Disconnect battery and check for inductor, output capacitor values. Check that R_{SEL} is open	Replace components as needed.
Waveform distortion (Deviation from waveshape in Figure 2 & 3)	Inductor wrong value Inductor saturated Poor inductor connection C_{OUT} value is too low C_{IN} value too low	Disconnect battery and check for inductor and input & output capacitor values.	Bad connection can cause higher line resistance. Repair PCB if needed.

Step 3A – Check the Output DC Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1Mohm or larger (e.g., Fluke 87), measure the voltage at the output of the MAX17220 device. Be sure to connect the negative "black" lead to ground and the positive "red" lead to the output "OUT" pin of the device. If the output pin is not easily assessable, place the leads across the output capacitor, C_{OUT}.

Use the following table to diagnose and fix associated problems:

Output Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	No connection from SMPS to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open.
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor.	PCB may have short.
Reading too low (< 1.71 VDC)	Inductor wrong value Inductor saturated Battery voltage low	Disconnect battery and check for inductor and EN connection. Check battery.	
1.71V ≥ Reading ≤ 1.89		No action.	Operational.
Reading too high (> 1.89 VDC)	Inductor wrong value Inductor saturated R_{SEL} installed (should be open).	Disconnect battery and check for inductor and EN connection. Check battery.	Battery voltage too high (Go back to Step 1).

Step 3B – Check the Output AC Voltage: Using an oscilloscope or digital storage scope (DSO), we will now measure the output ripple (AC) by probing the OUT pin on the MAX17220 device. To properly measure the output, avoiding RF pickup, it is recommended that a differential technique be employed.

If the circuit is operating correctly, the waveform should be a 1.8VDC output with a small ripple waveform superimposed on it. The ripple waveform should resemble that shown in the following figure:

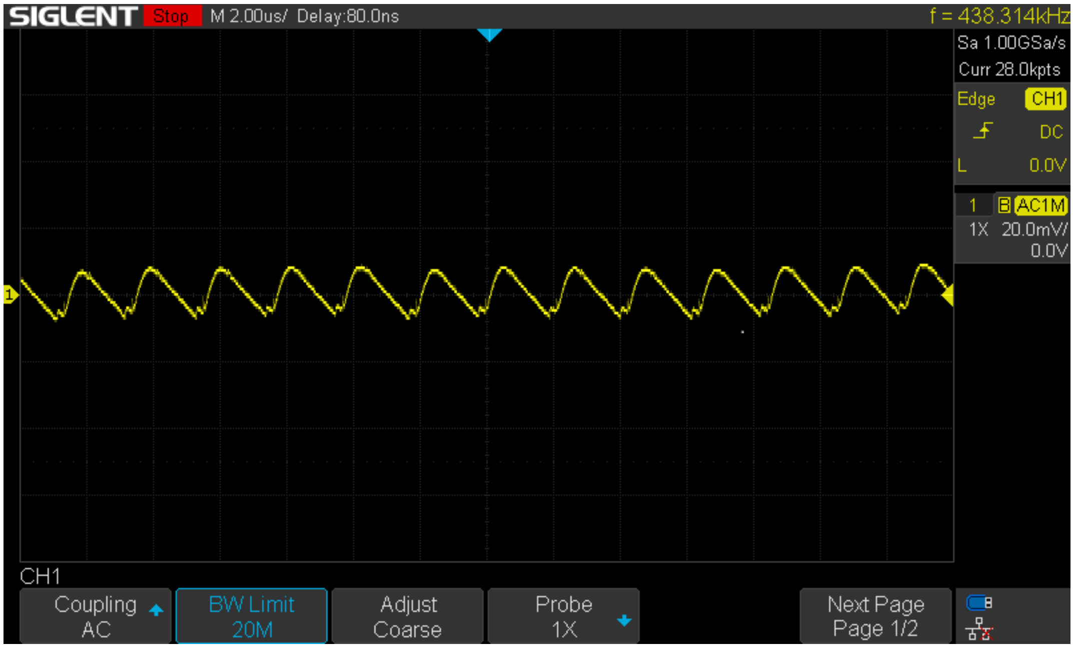

Figure 31: MAX17220 Output Ripple Waveform with 45mA Load Current

Use the following table to diagnose and fix associated problems:

Input Waveform	**Potential Cause**	**Action**	**Notes**
Ripple amplitude is too high (> 30mVpp)	C_{OUT} is too low. Defective output capacitor	Disconnect battery and check all connections with DMM ; Measure capacitor value	
Broadband Noise is too high	Load too large; environmental noise.	Check load and environmental noise.	Use differential probing on output to reduce environmental noise.
Transition Spikes too high (> 30mVp)	Load inductance; Input current not adequate	Check line inductance; Check input current with scope.	

Analog 5V SMPS Circuit Using the MAX20343H (Boost) Device

The following 5VDC circuit illustrates typical input and output power supply levels for a properly operating Switch-Mode Power Supply (SMPS) device in wearable medical/healthcare applications. Designed for associated line and load variations, the MAX20343H power supply can provide an effective solution without optical biosensor SNR degradation.

As shown in Figure 22, digital multimeters (DMM) can be used to probe the input and output ports to validate the supply voltage levels. Note that power supply output levels can vary due to various factors such as:

- Discharging battery
- Changing loads (e.g., device mode changes, devices waking up from sleep mode, etc.)

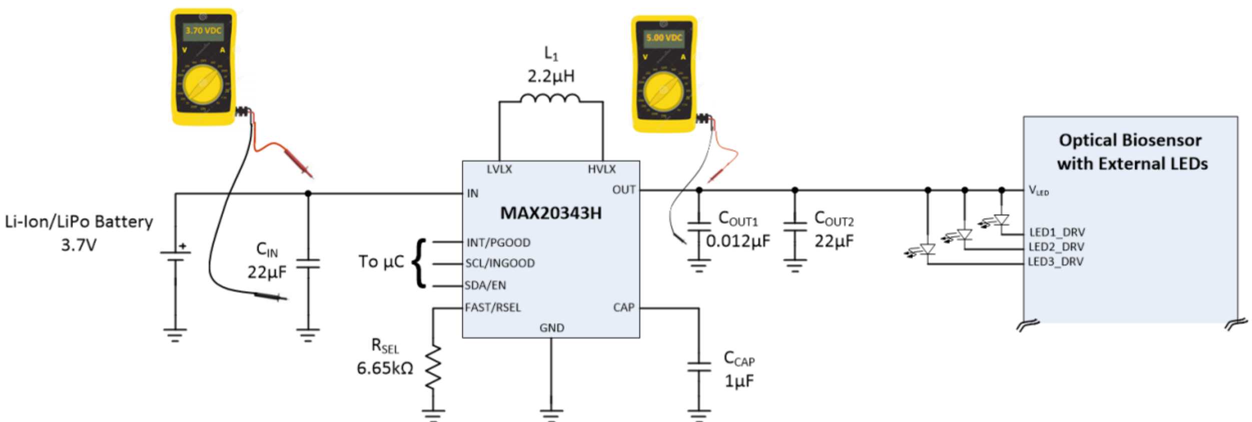

Figure 32. Analog 5VDC MAX20343H SMPS Circuit for Wearable Medical Applications

The following link can be used to obtain the MAX20343H circuit reference design files.

Design File Type	Name	Format	Link
Schematic	MAX20343HA_MPS_cookbook_Apps_P1_Schematic	Multiple	[Reference Design Files]
Bill of Materials	Build_BOM_MAX20343H_MPS_cookbook_Apps_P1	Excel	
Layout	MAX20343H_MPS_cookbook_Apps_P1_ODB++.tgz	Multiple	

Analog 5.0V SMPS Circuit Validation Checklist

The following table can be used as a checklist to validate operation of the analog 5.0V SMPS circuit using the MAX38640A device while connected to a load.

Step	Action	Procedure	Measurement	Need help?
1	Check input DC power supply	Measure voltage across battery	Reading range: 2.8V to 4.2V	Troubleshooting Instructions
2	Check input DC power supply	Measure voltage across C_{IN}	Reading range: 2.8V to 4.2V	
3	Check V_{OUT} DC level	Measure voltage across C_{OUT}	Reading range: 4.75V to 5.25V	
4	Check V_{OUT} DC level	Measure voltage across load	Reading range: 4.75V to 5.25V	
5	Check Output Noise Level	*Use differential oscilloscope probe method across C_{OUT}	Ripple Noise level should be <20mV_{PP}	

Typical Operating Characteristics

The following figures highlight the typical operating characteristics of the MAX20343H circuit under various load conditions. The test equipment used includes:

- Input Power Supply Source: B&K Precision BK1718 DC power supply
- Electronic Load: MAXREFDES1213 Smart Load using the MAX32630FTHR and MAX11311
- Benchtop DMM: B&K Precision BK2831E True RMS Bench digital multimeter

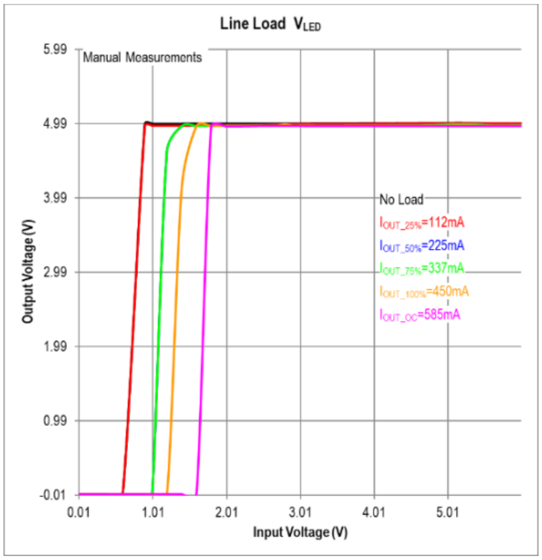

Figure 33. Line Load of the Analog 5V MAX20343H SMPS Circuit

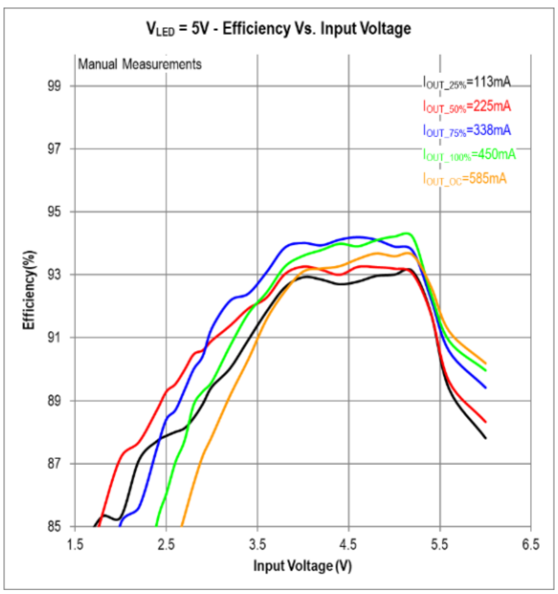

Figure 34. Efficiency of the Analog 5V MAX20343H SMPS Circuit

Typical Operating Characteristics

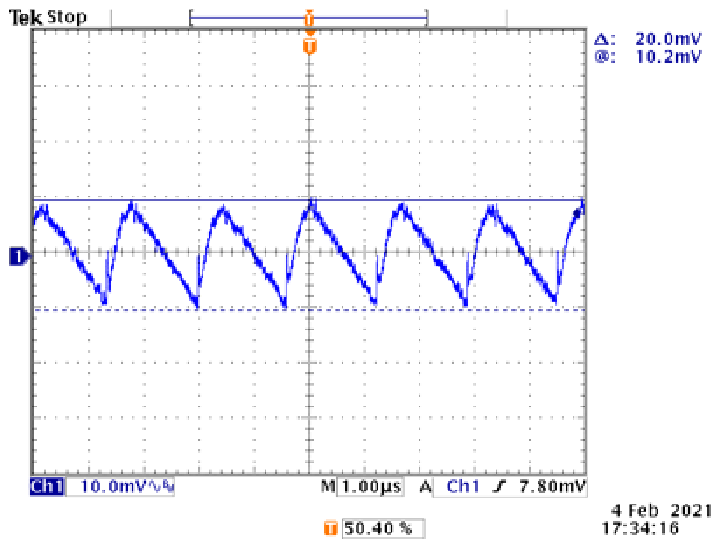

Figure 35. Typical Output Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

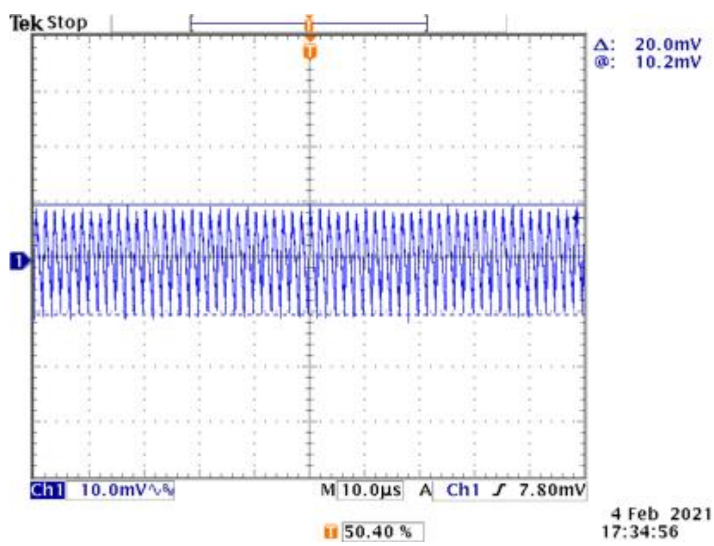

Figure 36. Typical Output Ripple Voltage (V_{IN} = 4.2VDC, I_S = 100mA)

Troubleshooting the MAX20343H (5V Output) SMPS Circuit

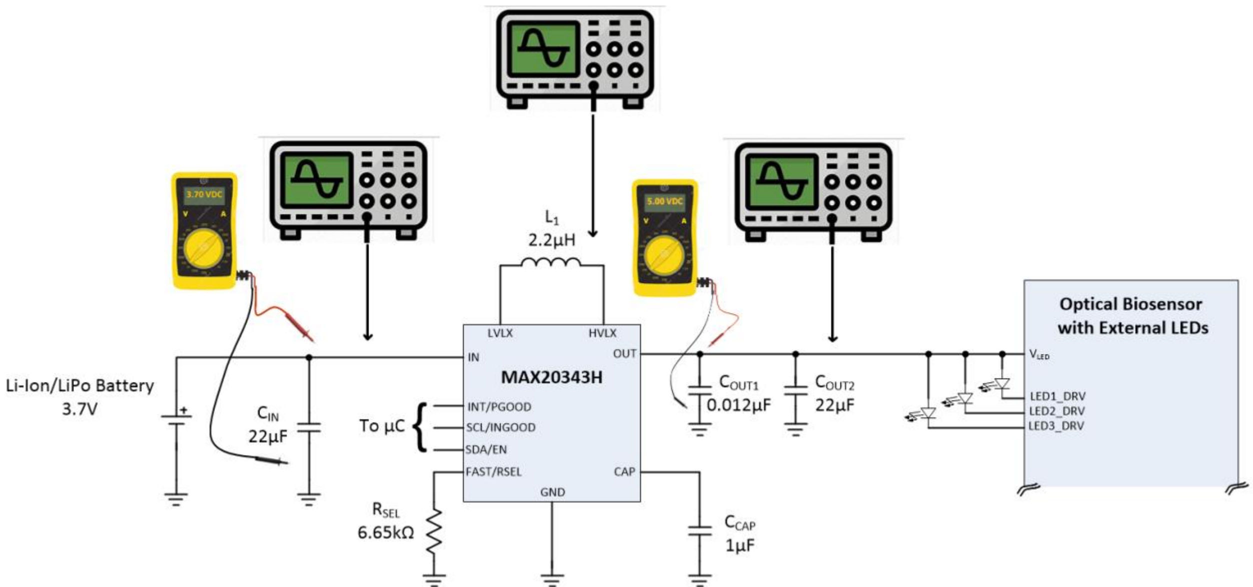

Figure 37. Troubleshooting the MAX20343H Circuit

<u>Troubleshooting the MAX20343H SMPS Circuit:</u>

Step 1. Check the Input Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage across at the input to the MAX20343H device. Be sure to connect the negative black lead to ground and the positive red lead to the input "IN" pin of the device. If the input pin is not easily assessable, place the leads across the input capacitor, C_{IN}.

Use the following table to diagnose and fix associated problems.

Input Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	Battery uncharged or defective	Disconnect battery and check voltage; if it reads 0V, recharge battery	Replace battery if it does not charge
	No connection from battery (IN or GND line)	Disconnect battery and test for conductivity from battery connector to device input	PCB may have an open
	Input capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
	EN pin (SDA/EN) connected to ground	Disconnect battery and test for conductivity from battery connector to device input	EN pin needs to be tied high for normal operation

Reading < 2.8V	Low battery charge Battery defective	Disconnect battery and check voltage; if it reads below 2.8V, recharge battery	Replace battery if it does not charge
2.8V ≥ Reading ≤ 4.2V		No action	Input voltage OK, proceed to step 2
Reading ≥ 4.2V	Defective battery	Replace battery	

Step 2. Check the Inductor Signal Waveform: Using an oscilloscope or digital storage scope (DSO), probe the HVLX pin on the MAX20343H device. If the input pin is not easily assessable, place the probe on the inductor end cap.

If the circuit is operating correcting, the waveform should be a pulse wave with minimal ringing on the rise and falling edges as shown in the following figure.

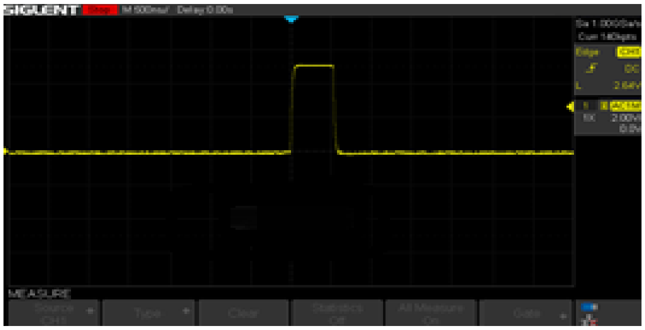

Figure 38. Typical MAX20343H HVLX Waveform with Light Load (10mA)

The 500ns pulse wave amplitude should be approximately equal to the input battery voltage. The pulse wave floor voltage should be within several 100mV of ground. The output frequency and duty cycle of the pulse wave is proportional to the load current. Figures 29 and 30 show the output wave and signal frequency under different load conditions.

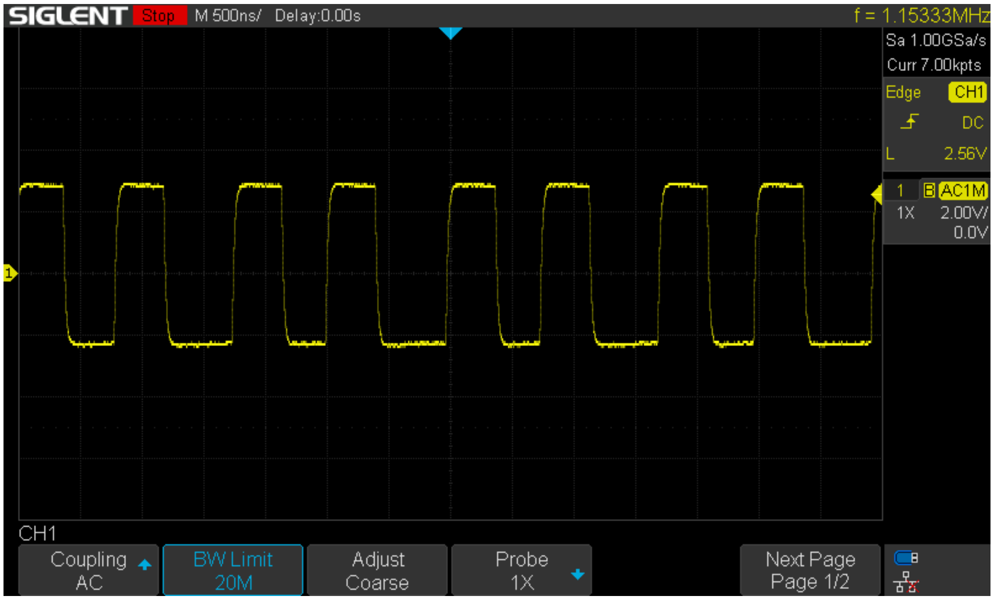

Figure 39. Typical MAX20343H HVLX Waveform with 125mA Load

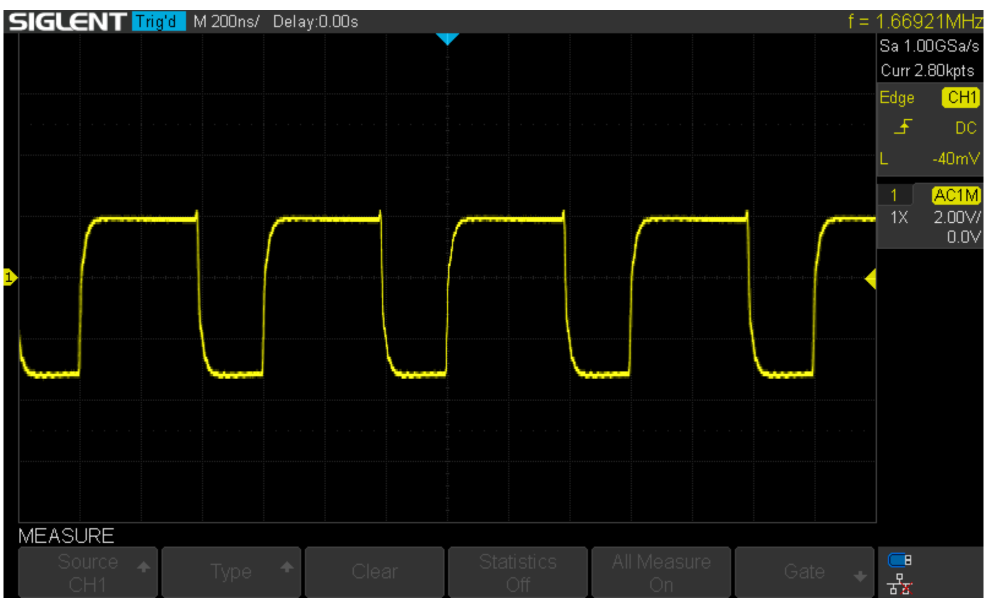

Figure 40. Typical MAX20343H HVLX Waveform with 246mA Load

Deviations from the ideal square wave can be used to effectively diagnose and fix many problems.

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Amplitude is not correct	Inductor open IN pin open EN is open or ground	Disconnect battery and check all connections with DMM	Repair PCB if needed
Duty Cycle is not correct (Does not correlate to the output voltage)	R_{SEL} is not the correct value (6.65kΩ), bad external resistor.	Disconnect battery and check R_{SEL} with a DMM (R-measurement)	Replace resistor with correct value resistor
	R_{SEL} pin open (V_O = 3.3V)	Check output for 3.3V; disconnect battery and test for conductivity from resistor to R_{SEL} pin	PCB may have an open
	R_{SEL} pin shorted to ground (V_O = 5.5V)	Check output for 5.5V; disconnect battery and measure resistance across capacitor	PCB may have short
Waveform distortion Rounded rising edge	Bad inductor connection	Reconnect inductor Replace inductor	Bad connection can cause higher line resistance

Step 3A. Check the Output DC Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage at the output of the MAX20343H device. Be sure to connect the negative black lead to ground and the positive red lead to the output “OUT” pin of the device. If the output pin is not easily assessable, place the leads across the output capacitor, C_{OUT}.

Use the following table to diagnose and fix associated problems:

Output Voltage Reading	**Potential Cause**	**Action**	**Notes**
Zero Volts/No Reading	No connection from SMPS to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
Reading too low (<4.75VDC)	Inductor wrong value Inductor saturated R_{SEL} has wrong value	Disconnect battery and check for inductor and/or resistor values	
4.75V ≥ Reading ≤ 5.25V		No action	Operational
Reading too high (>5.25VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Step 3B. Check the Output AC Voltage: Using an oscilloscope or digital storage scope (DSO), measure the output ripple (AC) by probing the OUT pin on the MAX20343H device. To measure the output and avoid RF pickup, it is recommended to use a differential probe technique.

If the circuit is operating correctly, the waveform should be a 1.8VDC output with a small ripple waveform superimposed on it. The ripple waveform should look like that shown in the following figure.

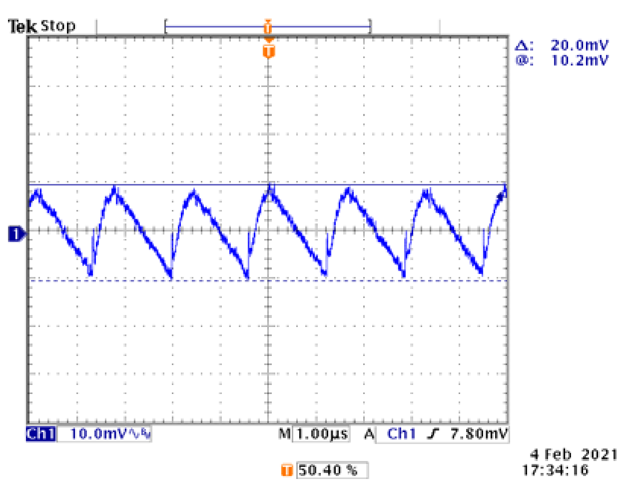

Figure 41. MAX20343H (5V) Output Ripple Waveform

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Ripple frequency does not match V_{HVLX} pulse wave frequency	Light load	Check load	
Broadband noise is too high	Load too large, environmental noise	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition spikes too high	Load inductance, input current not adequate	Check line inductance, check input current with scope.	

Analog 1.8V/Digital 1.8V/Analog 5.0V SMPS Circuit Using the MAX77642 Device

The following MAX77642 circuit illustrates typical input and output power supply levels for a properly operating Switch-Mode Power Supply (SMPS) device in wearable medical/healthcare applications. As shown in Figure 32, digital multimeters (DMM) can be used to probe the input and output ports to validate the supply voltage levels. Note that power supply output levels can vary due to various factors such as:

- Discharging battery
- Changing loads (e.g., device mode changes, devices waking up from sleep mode, etc.)

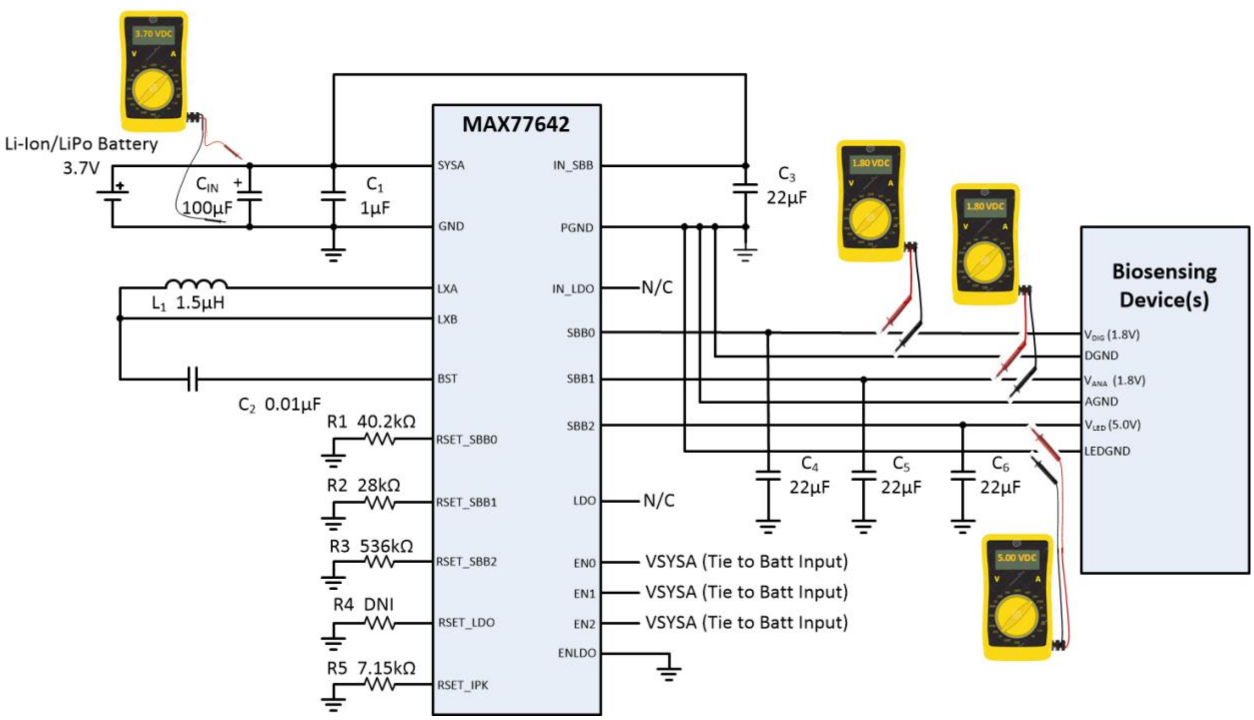

Figure 42. Analog 1.8V/Digital 1.8V/Analog 5.0V MAX77642 SMPS Circuit for Wearable Medical Applications

The following link can be used to obtain the MAX77642 circuit reference design files.

Design File Type	Name	Format	Link
Schematic	MAX77642_MPS_cookbook_Apps_P1_Schematic	Multiple	Reference Design Files
Bill of Materials	Build_BOM_MAX77642_MPS_cookbook_Apps_P1	Excel	
Layout	MAX77642_MPS_cookbook_Apps_P1_ODB++.tgz	Multiple	

MAX77642 1.8V/1.8V/5.0V SMPS Circuit Validation Checklist

The following table can be used as a checklist to validate operation of the 1.8V/1.8V/5.0V SMPS circuit using the MAX77642 device while connected to loads.

Step	Action	Procedure	Measurement	Need help?
1	Check input DC power supply	Measure voltage across Battery	Reading range: 2.8V to 4.2V	Troubleshooting Instructions
2	Check input DC power supply	Measure voltage across C_{IN}	Reading range: 2.8V to 4.2V	
3	Check V_{OUT} DC level	Measure SBB1 output DC voltage with reference to GND	Analog 1.8V Reading range: 1.71V to 1.89V	
4		Measure SBB0 output DC voltage with reference to GND	Digital 1.8V Reading range: 1.71V to 1.89V	
5		Measure SBB2 output DC voltage with reference to GND	Analog 5V Reading range: 4.75V to 5.25V	
6	Check Analog 1.8V Output Noise Level	*Use differential oscilloscope probe method across C_5	Ripple Noise level should be <20mV_{PP}	
			Switch spikes should be <30mV_P	
7	Check Digital 1.8V Output Noise Level	*Use differential oscilloscope probe method across C_4	Ripple Noise level should be <20mV_{PP}	
			Switch spikes should be <30mV_P	
8	Check Analog 5.0V Output Noise Level	*Use differential oscilloscope probe method across C_6	Ripple Noise level should be <20mV_{PP}	
			Switch spikes should be <30mV_P	

Typical Operating Characteristics

The following figures highlight the typical operating characteristics of the MAX77642 circuit under various load conditions. The test equipment used includes:

- Input Power Supply Source: B&K Precision BK1718 DC power supply
- Electronic Load: MAXREFDES1213 Smart Load using the MAX32630FTHR and MAX11311
- Benchtop DMM: B&K Precision BK2831E True RMS Bench digital multimeter

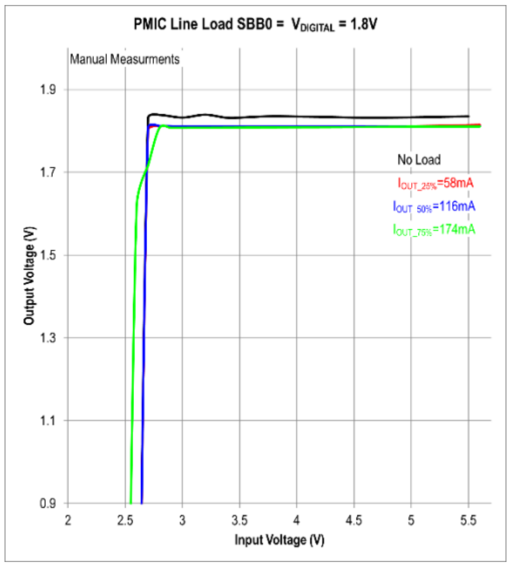

Figure 43. Line Load of the Digital 1.8V MAX77642 SMPS Circuit

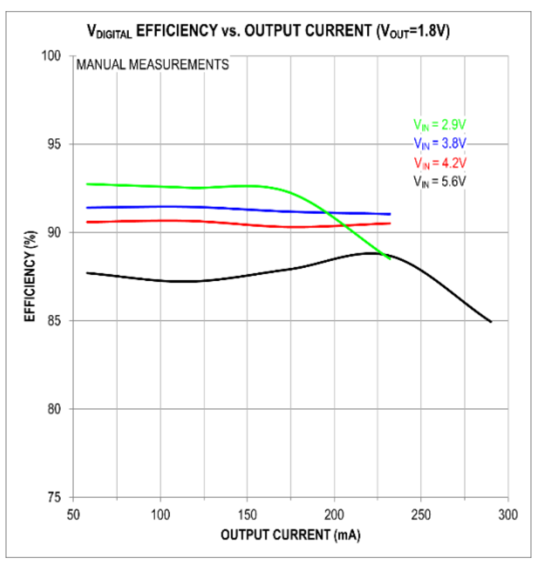

Figure 44. Efficiency of the Digital 1.8V MAX77642 SMPS Circuit

Typical Operating Characteristics

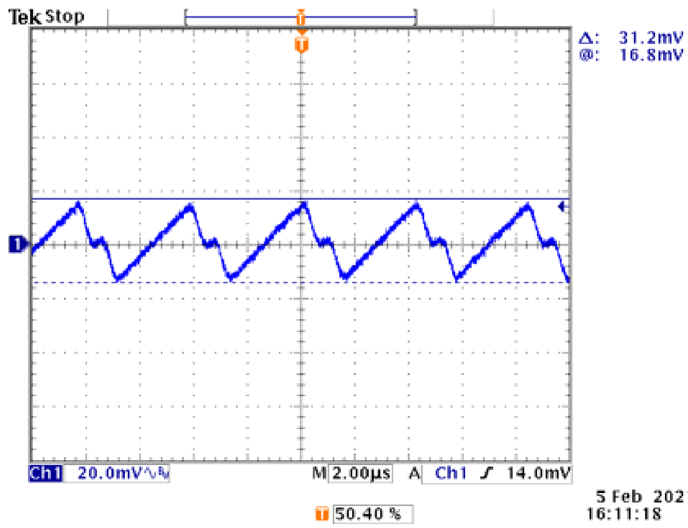

Figure 45. Typical Output Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

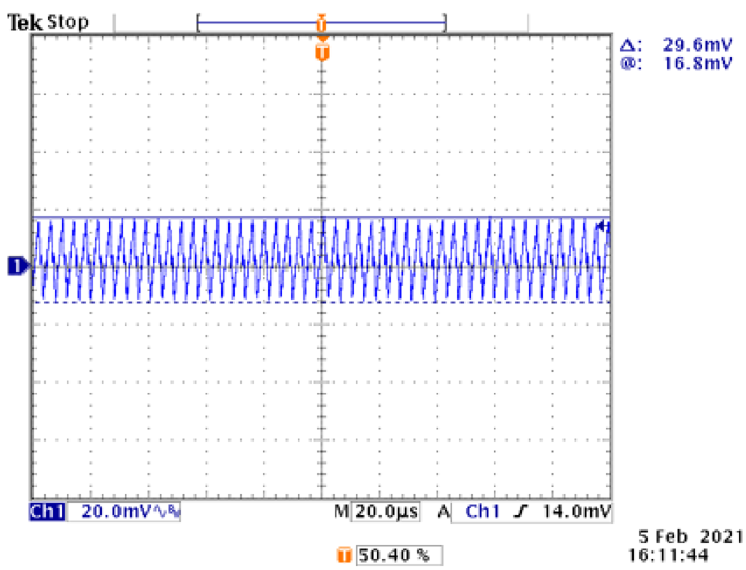

Figure 46. Typical Output Ripple Voltage (V_{IN} = 4.2VDC, I_S = 100mA)

Typical Operating Characteristics

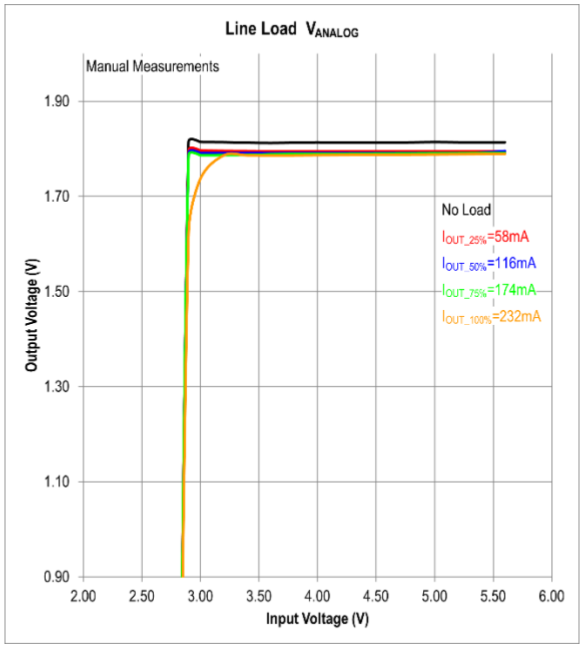

Figure 47. Line Load of the Analog 1.8V MAX77642 SMPS Circuit

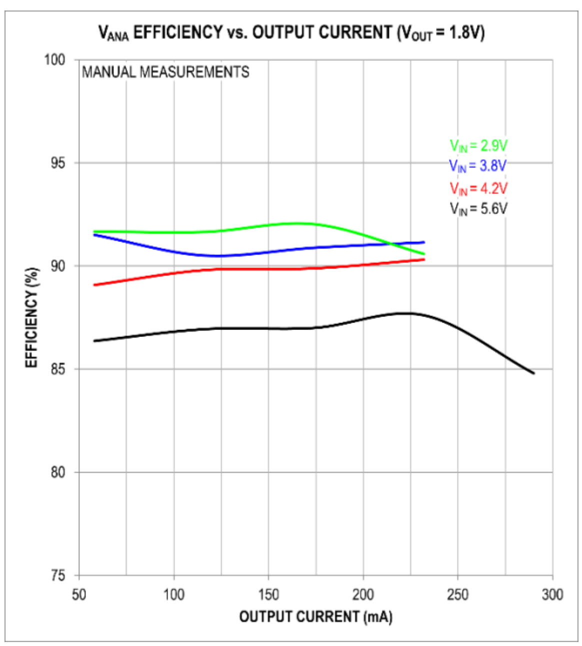

Figure 48. Efficiency of the Analog 1.8V MAX77642 SMPS Circuit

Typical Operating Characteristics

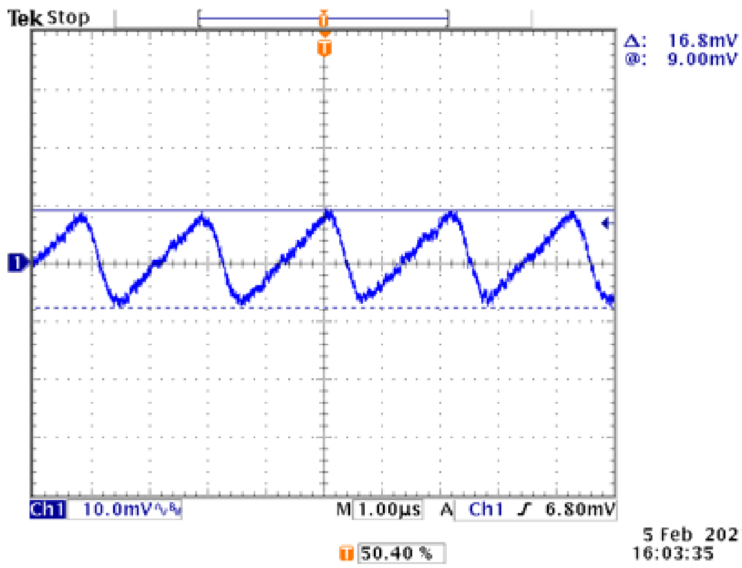

Figure 49. Typical Output Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

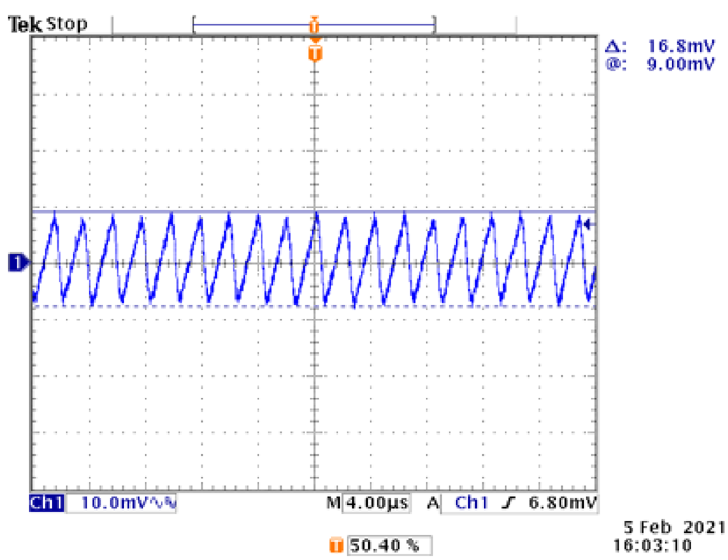

Figure 50. Typical Output Ripple Voltage (V_{IN} = 4.2VDC, I_S = 100mA)

Typical Operating Characteristics

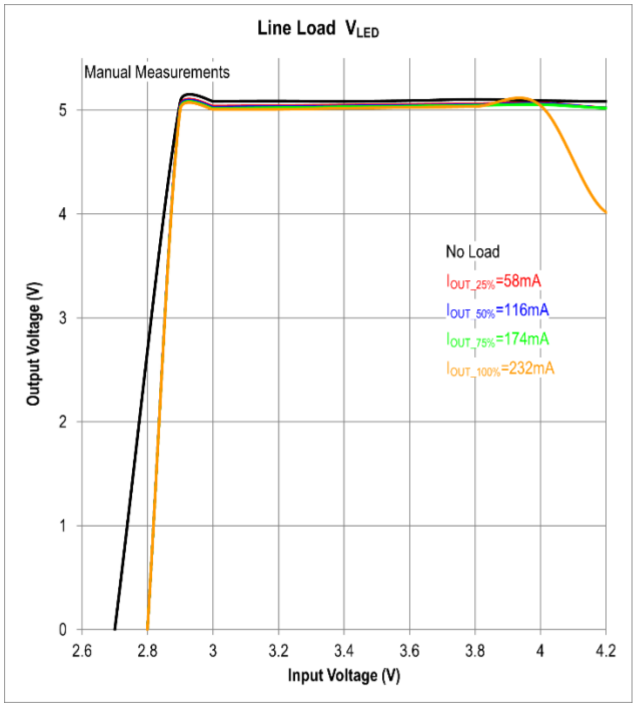

Figure 51. Line Load of the Analog 5V MAX77642 SMPS Circuit

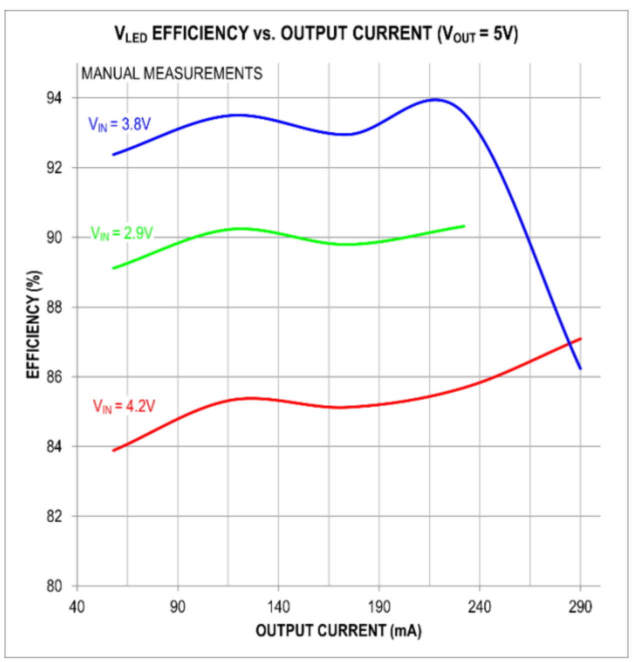

Figure 52. Efficiency of the Analog 5V MAX77642 SMPS Circuit

Typical Operating Characteristics

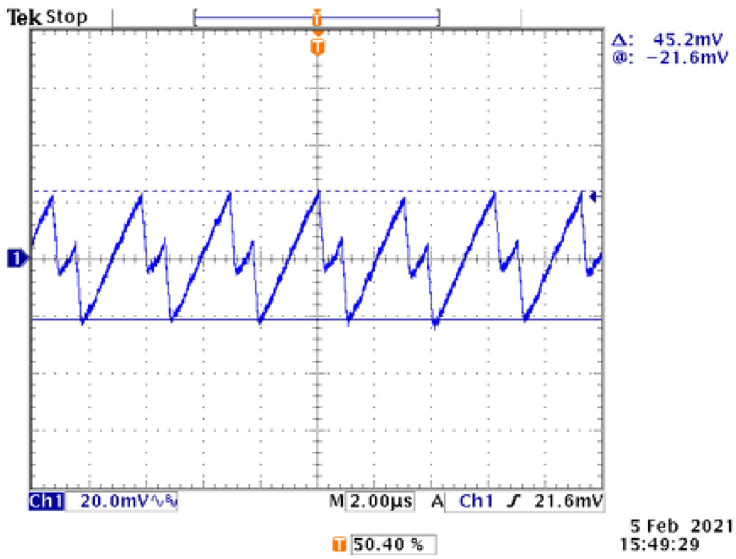

Figure 53. Typical Out Ripple Characteristic (V_{IN} = 4.2VDC, I_S = 100mA)

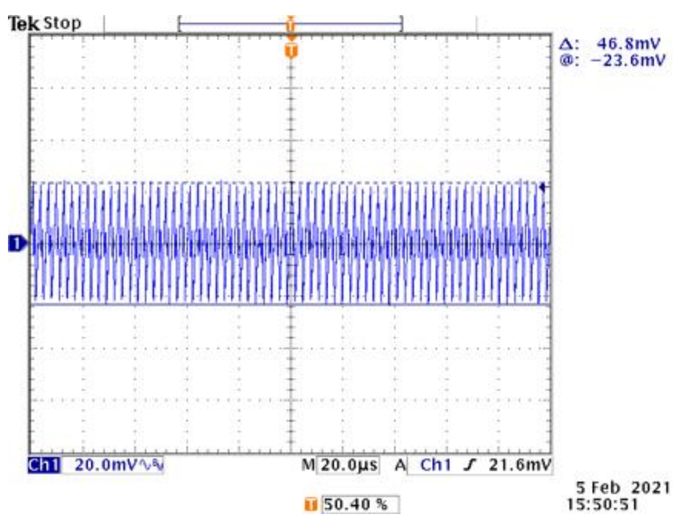

Figure 54. Typical Output Ripple Voltage (V_{IN} = 4.2V, I_S = 100mA)

Troubleshooting the MAX77642 (1.8V/1.8V/5V Output) SMPS Circuit

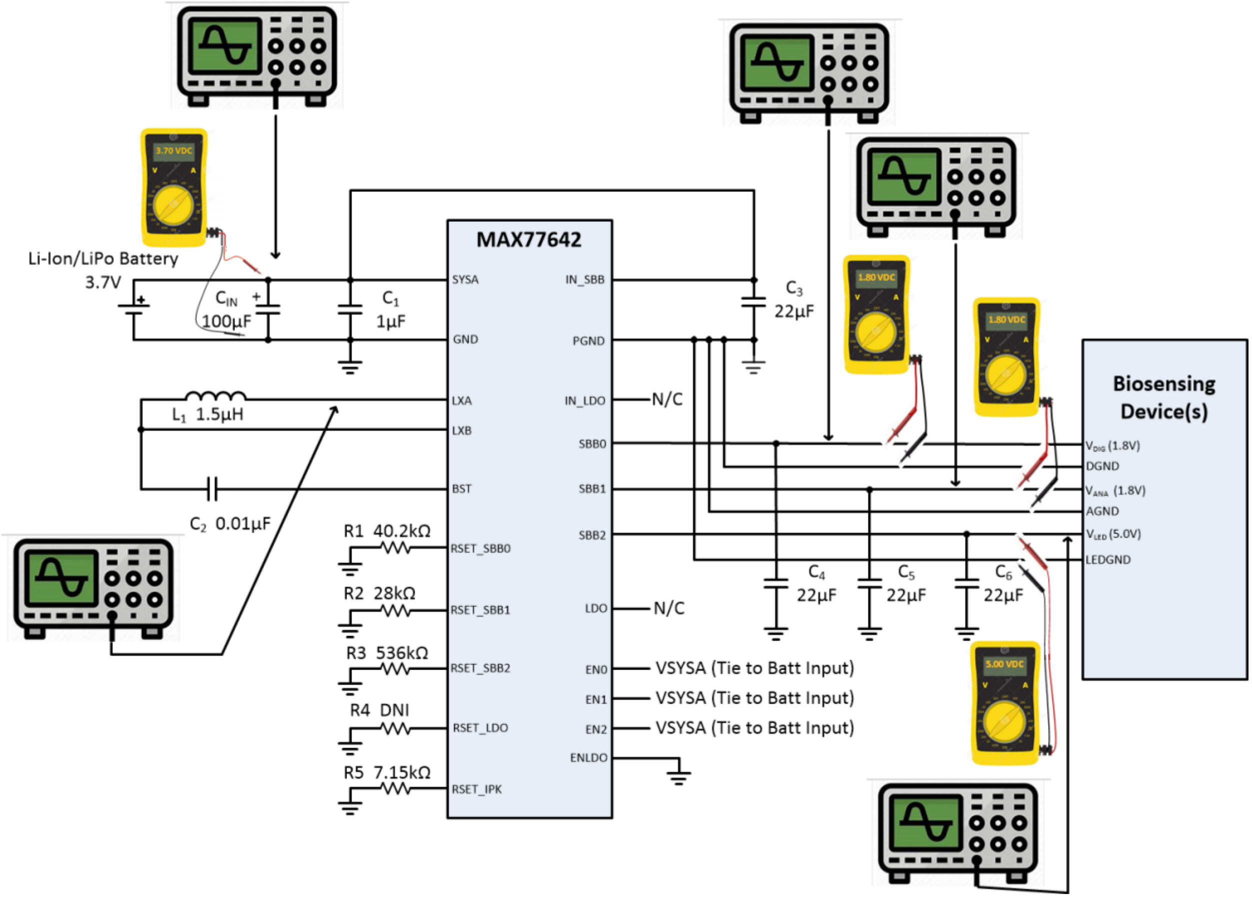

Figure 55. Troubleshooting the MAX77642 SMPS Circuit

<u>Troubleshooting the MAX77642 SMPS Circuit:</u>

Step 1. Check the Input Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage across at the input to the MAX77642 device. Be sure to connect the negative black lead to ground and the positive red lead to the input "IN" pin of the device. If the input pin is not easily assessable, place the leads across the input capacitor, C_{IN}.

Use the following table to diagnose and fix associated problems:

Input Voltage Reading	Potential Cause	Action	Notes
Zero Volts/No Reading	Battery uncharged or defective	Disconnect battery and check voltage; if it reads 0V, recharge battery	Replace battery if it does not charge
	No connection from battery (IN or GND line)	Disconnect battery and test for conductivity from battery connector to device input	PCB may have an open

	Input capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
Reading < 2.8VDC	Low battery charge Battery defective	Disconnect battery and check voltage; if it reads below 2.8V, recharge battery	Replace battery if it does not charge
2.8VDC ≥ Reading ≤ 4.2VDC		No action	Operational
Reading ≥ 4.2VDC	Defective battery	Replace battery	

Step 2. Check the Inductor Signal Waveform: Using an oscilloscope or digital storage scope (DSO), probe the LXA pin on the MAX77642 device. If the input pin is not easily assessable, place the probe on the (LXA) inductor end cap.

If the circuit is operating correcting, the waveform should be a series of pulse waves wave with minimal ringing on the rise and falling edges as shown in the following figure.

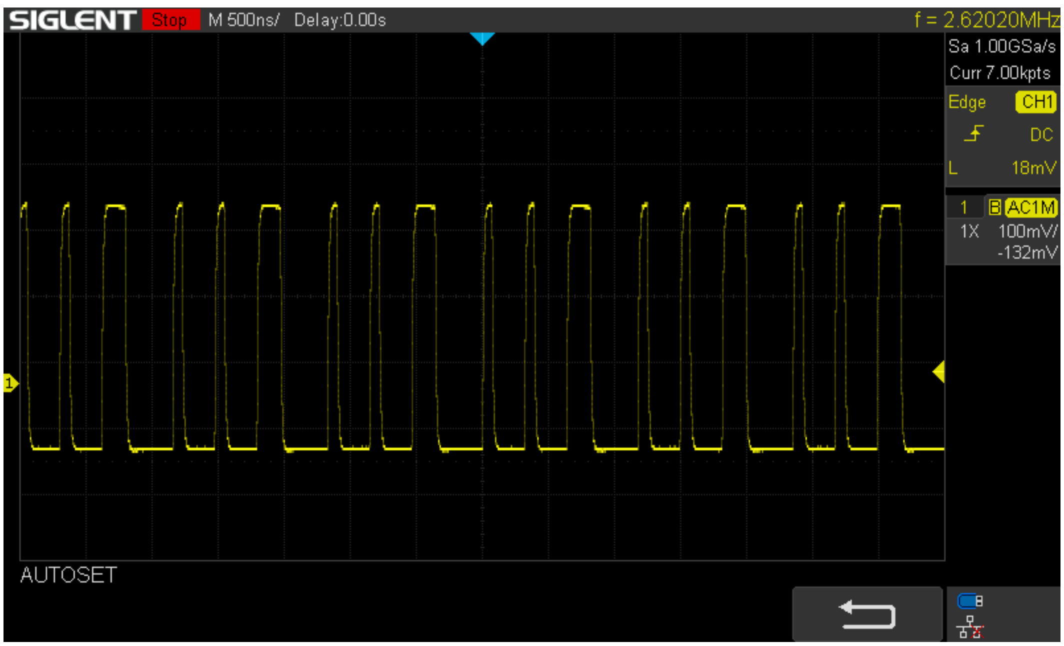

Figure 56. Typical MAX77642 LXA Waveform (SSB0 & SSB1 I_{OUT} = 1.2mA; SSB2 I_{OUT} = 126.1mA)

The pulse waveforms demonstrate the time multiplexing of the of three switch-mode power supplies sharing a single inductor (A.K.A. SIMO Power Supply Device).

Deviations from the ideal series of pulse waves can be used to effectively diagnose and fix many problems.

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Amplitude is not correct	Inductor open, IN pin open	Disconnect battery and check all connections with DMM	Repair PCB if needed
Duty Cycle is not correct (missing pulses)			
SSB0 Pulse Missing	EN0 shorted to GND	Check SSB0 Output for 0V. Disconnect battery and test for conductivity from EN0 Pin to GND.	PCB may have short
SSB1 Pulse Missing	EN1 shorted to GND	Check SSB1 Output for 0V. Disconnect battery and test for conductivity from EN0 Pin to GND.	PCB may have short
SSB2 Pulse Missing	EN2 shorted to GND	Check SSB2 Output for 0V; disconnect battery and test for conductivity from EN0 Pin to GND	PCB may have short
Duty Cycle is not correct (Pulse Widths not correct)	Output Voltage Select Resistors, defective device	Identify SSBx channel associated with incorrect PW and follow associated steps below	
SSB0 PW Incorrect	RSET_SSB0 shorted to GND (SSB0 Vo = 0.5V)	Disconnect battery and test for 40.2kΩ to GND	Bad/wrong resistor, PCB may have short
	RSET_SSB0 pin open (SSB0 Vo = 5.2V)	Disconnect battery and test for conductivity from resistor to RSET_SSB0 pin.	PCB may have an open, bad solder connection
	Wrong RSET_SSB0 resistor value	Disconnect battery and test for 40.2kΩ to GND.	Bad/wrong resistor installed
SSB1 PW Incorrect	RSET_SSB1 shorted to GND (SSB1 Vo = 0.5V)	Disconnect battery and test for 28kΩ to GND.	Bad (shorted) resistor, PCB may have short
	RSET_SSB0 pin open (SSB1 Vo = 5.2V)	Disconnect battery and test for conductivity from resistor to RSET_SSB1 pin.	PCB may have an open, bad solder connection
	Wrong RSET_SSB0 resistor value	Disconnect battery and test for 28kΩ to GND.	Bad/wrong resistor installed
SSB2 Pulse Missing	RSET_SSB2 shorted to GND (SSB2 Vo = 0.5V)	Disconnect battery and test for 536kΩ to GND.	Bad (shorted) resistor, PCB may have short
	RSET_SSB2 pin open (SSB2 Vo = 5.5V)	Disconnect battery and test for conductivity from resistor to RSET_SSB2 pin	PCB may have an open, bad solder connection

	Wrong RSET_SSB2 resistor value	Disconnect battery and test for 536kΩ to GND	Bad/wrong resistor installed
Waveform distortion Rounded rising edge	Bad inductor connection	Reconnect or replace inductor	Bad connection can cause higher line resistance

Step 3A. Check the Output DC Voltage: Using a digital multimeter (DMM) with an internal impedance of a 1MΩ or larger (e.g., Fluke 87), measure the voltage at the three outputs of the MAX77642 device. Be sure to connect the negative black lead to ground and the positive red lead to the associated SSBx channel output "OUT" pin of the device. If the output pin is not easily assessable, place the leads across the associated output capacitor, C_{OUT}.

Use the following table to diagnose and fix associated SSB0 (1.8VDC) output problems:

Output Voltage Reading	Potential Cause	Action	Notes
SSB0: Zero Volts/No Reading	No connection from SSB0 to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
SSB0: Reading too low (<1.71VDC)	Inductor wrong value Inductor saturated RSET_SSB0 has wrong value	Disconnect battery and check for inductor and/or resistor values	
1.71V ≥ Reading ≤ 1.89V		No action	Operational
Reading too high (>1.89VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Use the following table to diagnose and fix associated SSB1 (1.8VDC) output problems.

Output Voltage Reading	**Potential Cause**	**Action**	**Notes**
SSB1: Zero Volts/No Reading	No connection from SSB0 to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor	PCB may have short
SSB1: Reading too low (<1.71VDC)	Inductor wrong value Inductor saturated RSET_SSB1 has wrong value	Disconnect battery and check for inductor and/or resistor values	
1.71V ≥ Reading ≤ 1.89V		No action	Operational
SSB1 Reading too high (>1.89VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Use the following table to diagnose and fix associated SSB2 (5.0VDC) output problems.

Output Voltage Reading	**Potential Cause**	**Action**	**Notes**
SSB2: Zero Volts/No Reading	No connection from SSB0 to C_{OUT}	Disconnect battery and test for conductivity from output to C_{OUT}	PCB may have an open
	Output capacitor shorted to ground	Disconnect battery and check for continuity across capacitor.	PCB may have short
SSB2: Reading too low (<4.75VDC)	Inductor wrong value Inductor saturated RSET_SSB2 has wrong value	Disconnect battery and check for inductor and/or resistor values	
4.75V ≥ Reading ≤ 5.25V		No action	Operational
SSB1 Reading too high (>5.259VDC)	R_{SEL} has wrong value	Disconnect battery and check R_{SEL} value	

Step 3B. Check the Output AC Voltage: Using an oscilloscope or digital storage scope (DSO), measure the output ripple (AC) by probing the three outputs of the MAX77642 device. To measure the output and avoid RF pickup, it is recommended to use a differential probe technique.

If the circuit is operating correctly, the SSB0 waveform should be a 1.8VDC (digital) output with a small ripple waveform superimposed on it. The ripple waveform should look like that shown in the following figure.

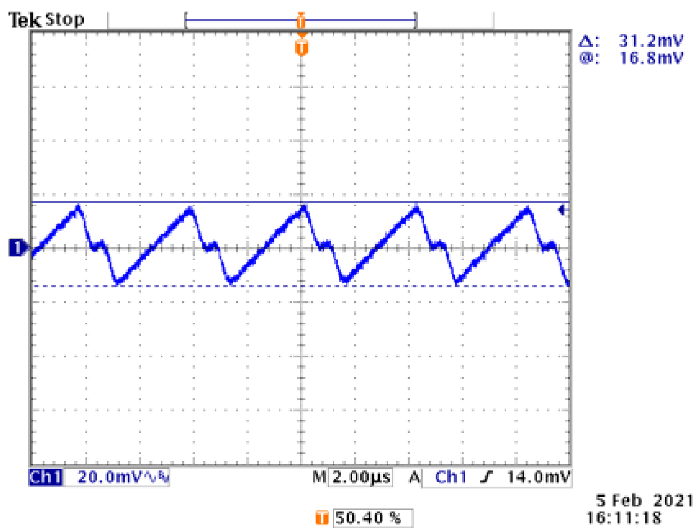

Figure 57. MAX77642 SSB0 (Dig 1.8V) Ripple Waveform (V_{IN} = 4.2V, I_{OUT} = 100mA)

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Broadband Noise is too high	Load too large, environmental noise	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition Spikes too high	Load inductance too large, input current not adequate	Check line inductance, check input current with scope.	

If the circuit is operating correctly, the SSB1 waveform should be a 1.8VDC (analog) output with a small ripple waveform superimposed on it. The ripple waveform should look like that shown in the following figure.

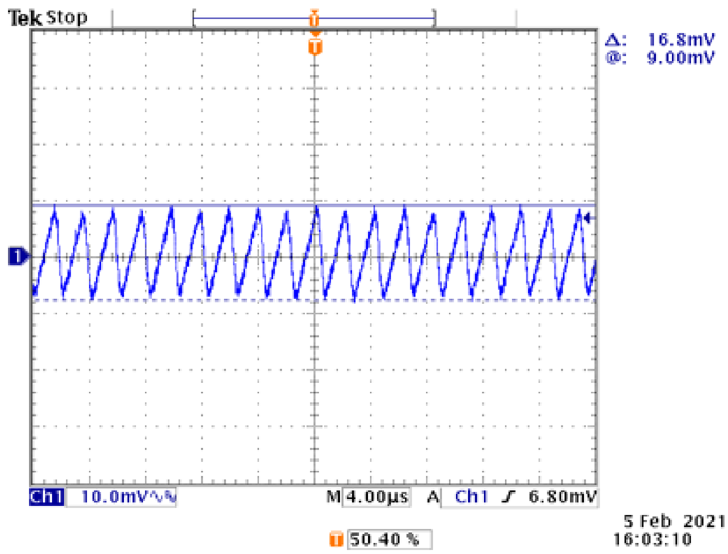

Figure 58. MAX77642 SSB1 (Analog 1.8V) Ripple Waveform (V_{IN} = 4.2V, I_{OUT} = 100mA)

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Broadband Noise is too high	Load too large, environmental noise	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition Spikes too high	Load inductance too large, input current not adequate	Check line inductance, check input current with scope	

If the circuit is operating correctly, the SSB2 waveform should be a 5.0VDC (for LEDs) output with a small ripple waveform superimposed on it. The ripple waveform should look like that shown in the following figure.

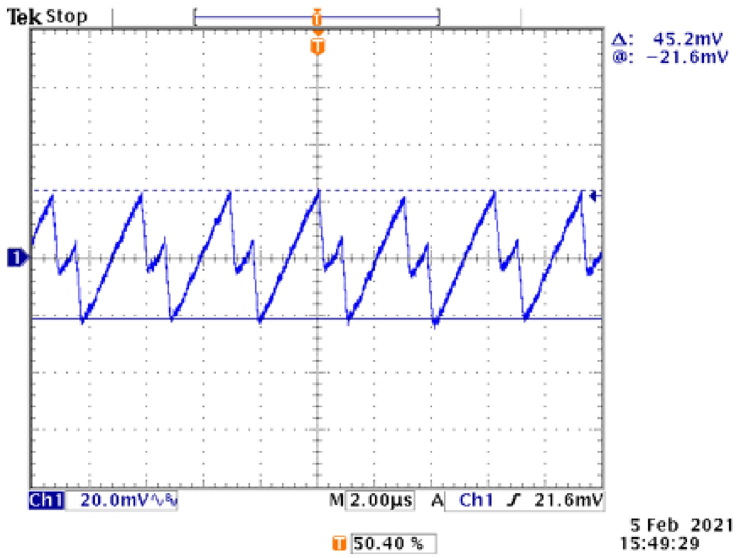

Figure 59. MAX77642 SSB2 (5.0V) Ripple Waveform (V_{IN} = 4.2V, I_{OUT} = 100mA)

Use the following table to diagnose and fix associated problems.

Input Waveform	Potential Cause	Action	Notes
Ripple amplitude is too high	Wrong capacitor value, defective capacitor	Disconnect battery and check all connections with DMM, measure capacitor value	
Broadband Noise is too high	Load too large, environmental noise	Check load and environmental noise	Use differential probing on output to reduce environmental noise
Transition Spikes too high	Load inductance too large, input current not adequate	Check line inductance, check input current with scope	

System Integration Guidelines

When integrating the SMPS circuits with biosensor devices, a "Star" power supply routing configuration should be implemented. See Figure 50 for an example of this topology type.

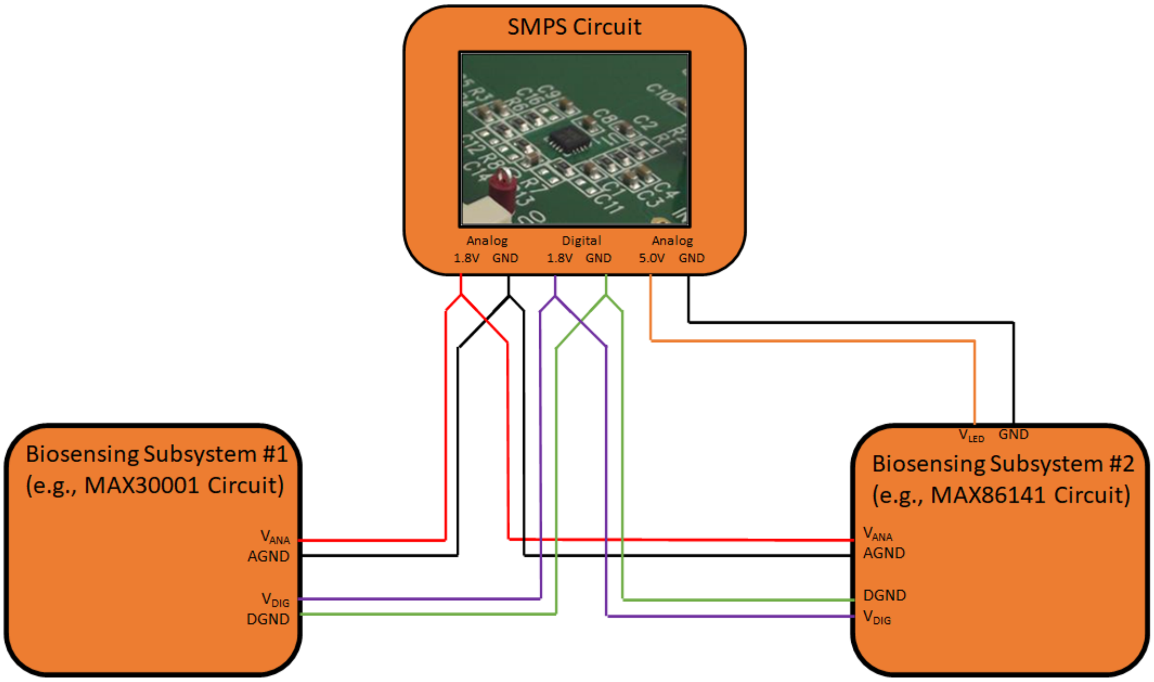

Figure 60. Power Supply "Star" Routing Topology

Along with the implementation of this power connection scheme, the following requirements should be met as well:

- Design the power and return line trace geometry for the required load current
- Route power and return lines as a parallel pair to each biosensing subsystem
- Avoid routing the power pair over any ground planes, remove ground plane area if needed
- Keep the digital power line pair separated from the analog power line pair (or route a separate ground shield line between the pair)
- Do not route the analog power line pair near any noise producing sources such as high frequency signal lines, antennas, etc.
- Avoid ground loops
- Follow the reference design layout guidelines in the biosensor device data sheet and/or evaluation kit documentation
- If layer stack-up differences exist between the SMPS circuit reference design and the subcircuits (e.g., MAX86141), integrate the SMPS circuit design with the larger layer stack-up definition