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Introduction to Digital Stethoscopes and Electrical Component Selection Criteria

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Abstract: This application note provides an overview of the basic operation and design considerations for a digital stethoscope. The similarities between a digital stethoscope and an acoustic stethoscope, which is the older generation of the instrument, are explained. The article then outlines the more sophisticated features of the newer digital designs, including audio recording and playback. When discussing design considerations for a digital stethoscope, it details the importance of the audio signal path, presents considerations for audio codec electronics, and outlines the audio frequency requirements for cardiac and pulmonary sound. The article also addresses the system's subfunctions which include data storage and transfer, display and backlighting, power management, and battery management.

Overview

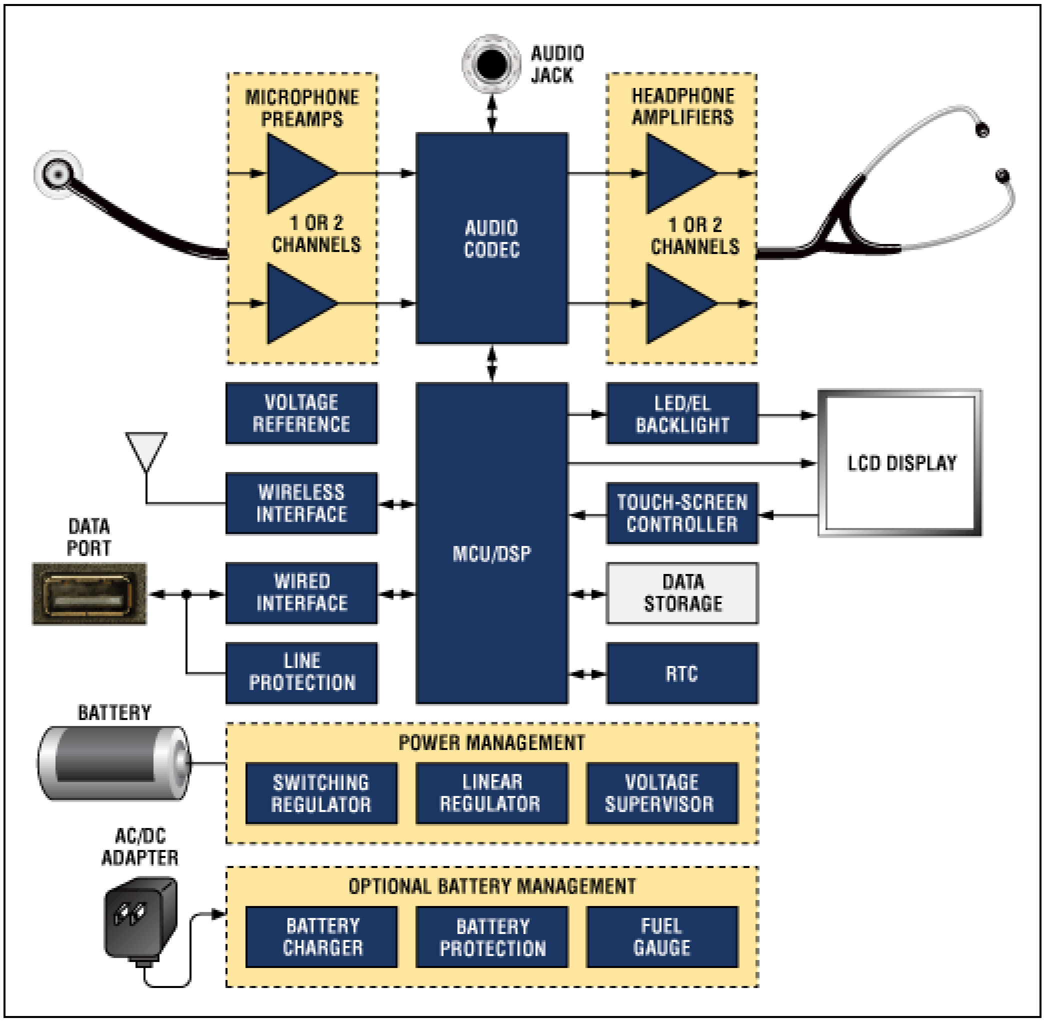
A stethoscope, whether acoustic or digital, is used mainly to listen to heart and lung sounds in the body as an aid to diagnosis. Listening, or auscultation, has been done with acoustic stethoscopes for almost two hundred years; recently, electronic digital stethoscopes have been developed.

The goal of a basic digital stethoscope is to have it retain the look and feel of an acoustic stethoscope but to improve listening performance. In addition, high-end digital stethoscopes offer sophisticated capabilities such as audio recording and playback. They also provide data to visually chart results by connecting to an off-instrument display such as a computer monitor. This advanced functionality increases the physician's diagnostic capability. Maintaining the existing acoustic stethoscope form (i.e., that "look and feel") while improving the performance digitally requires the use of small, low-power solutions.

Audio Signal Path

The essential elements of a digital stethoscope are the sound transducer, the audio codec electronics, and the speakers. The sound transducer, which converts sound into an analog voltage, is the most critical piece in the chain. It determines the diagnostic quality of the digital stethoscope and ensures a familiar user experience to those accustomed to acoustic stethoscopes.

The analog voltage needs to be conditioned and then converted into a digital signal using an audio analog-to-digital converter (ADC) or audio codec. Some digital stethoscopes have noise cancellation that requires a secondary sound transducer or microphone to record the ambient noise so that it can be removed digitally. In this approach, two audio ADCs are required.



Functional block diagram of a digital stethoscope. For a list of Maxim's recommended digital-stethoscope solutions, please go to: www.maximintegrated.com/stethoscope.

Once in the digital domain, a microcontroller unit (MCU) or digital signal processor (DSP) performs signal processing, including ambient noise reduction and filtering, to limit the bandwidth to the range for cardiac or pulmonary listening. The processed digital signal is then converted back to analog by an audio digital-to-analog converter (DAC) or audio codec.

A headphone or speaker amplifier conditions the audio signal before outputting to a speaker. A single speaker can be used below where the stethoscope tube bifurcates, with the amplified sound traveling through the binaural tubes to the ears. Alternatively, two speakers can be used, with one speaker at the end of each earpiece. The frequency response of the speaker is similar to that of a bass speaker because of the low-frequency sound production needed. Depending on the implementation, one or two speaker amplifiers are used.

A stethoscope must be most sensitive to cardiac sound in the 20Hz to 400Hz range and to pulmonary sound in the 100Hz to 1200Hz range. Note that the frequency ranges vary by manufacturer, and the DSP algorithms filter out sound beyond these optimal ranges.

Data Storage and Transfer

Once the captured sound is converted to an analog voltage, it can be sent out through an audio jack and played back on either a computer or through the digital stethoscope. The captured sound can also be manipulated digitally. It can be stored in the stethoscope using internal or removable nonvolatile (NV) memory like EEPROM or flash, and then played back through the stethoscope's speakers; or it can be transferred to a computer for further analysis. Adding a real-time clock (RTC) facilitates tagging the recording with time and date. The sound is commonly transferred with a wired interface, such as USB, or with a wireless interface like Bluetooth® or another proprietary wireless interface.

Display and Backlighting

Some digital stethoscopes have a small, simple display due to the limited space available; others have only buttons and LED indicators. Backlighting for the display is required because the ambient lighting during the procedure is often at a low level. The small display requires just one or two white light-emitting diodes (WLEDs) controlled by an LED driver or an electroluminescent (EL) panel controlled by an EL driver. Most of the user-interface buttons can be eliminated by adding a touch-screen display and controller.

Power Management

Most digital stethoscopes use either one or two AAA 1.5V primary batteries. This design requires a step-up, or boost, switching regulator to increase the voltage to 3.0V or 5.0V, depending on the circuitry utilized.

If a single 1.5V battery is installed, the switching regulator will probably be on all the time, making low quiescent current a critical factor for long battery life. The longer the battery life, the more convenient the digital stethoscope is to use and the closer the experience will be to an acoustic stethoscope.

When using two 1.5V batteries in series, the switching regulator can be left on all the time or shut down when not in use. If the circuit operates from 3.6V down to 1.8V, then a switching regulator may not be needed. Cost will be reduced and space saved. A low-battery warning is required so that a patient's examination need not be interrupted to replace the battery.

Battery Management

Rechargeable batteries can be used; the best choice is a single-cell Li+ battery. If a rechargeable battery is used, a battery charger is required either in the digital stethoscope or in a charging cradle. A fuel gauge is the best solution to accurately determine the remaining battery life. If the battery is removable, then authentication is also required for safety and aftermarket management.

Related Parts

DS1337	I²C Serial Real-Time Clock	Free Samples
DS1390	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
DS1394	Low-Voltage SPI/3-Wire RTCs with Trickle Charger	Free Samples
MAX11800	Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface	Free Samples
MAX11803	Low-Power, Ultra-Small Resistive Touch-Screen Controllers with I²C/SPI Interface	Free Samples
MAX1233	±15kV ESD-Protected Touch-Screen Controllers Include DAC and Keypad Controller	Free Samples
MAX1234	±15kV ESD-Protected Touch-Screen Controllers Include DAC and Keypad Controller	Free Samples
MAX1574	180mA, 1x/2x, White LED Charge Pump in 3mm x 3mm TDFN	
MAX1916	Low-Dropout, Constant-Current Triple White LED Bias Supply	Free Samples
MAX1984	Ultra-Efficiency White LED Drivers	Free Samples
MAX1986	Ultra-Efficiency White LED Drivers	Free Samples
MAX4060	Differential Microphone Preamplifiers with Internal Bias and Complete Shutdown	
MAX4061	Differential Microphone Preamplifiers with Internal Bias and Complete Shutdown	Free Samples
MAX4062	Differential Microphone Preamplifiers with Internal Bias and Complete Shutdown	Free Samples
MAX9723	Stereo DirectDrive® Headphone Amplifier with BassMax, Volume Control, and I²C	Free Samples
MAX9724A	60mW, DirectDrive, Stereo Headphone Amplifier with Low RF Susceptibility and Shutdown	Free Samples
MAX9724B	60mW, DirectDrive, Stereo Headphone Amplifier with Low RF Susceptibility and Shutdown	Free Samples
MAX9812	Tiny, Low-Cost, Single/Dual-Input, Fixed-Gain Microphone Amplifiers with Integrated Bias	Free Samples
MAX9813	Tiny, Low-Cost, Single/Dual-Input, Fixed-Gain Microphone Amplifiers with Integrated Bias	Free Samples
MAX9820	DirectDrive Headphone Amplifier with External Gain	Free Samples
MAX9856	Low-Power Audio CODEC with DirectDrive Headphone Amplifiers	Free Samples
MAX9860	16-Bit Mono Audio Voice Codec	Free Samples

MAX9867	Low-Power, Stereo Audio Codec	Free Samples
MAXQ2000	Low-Power LCD Microcontroller	Free Samples
MAXQ2010	16-Bit Mixed-Signal Microcontroller with LCD Interface	Free Samples
MAXQ610	16-Bit Microcontroller with Infrared Module	Free Samples
MAXQ612	16-Bit Microcontrollers with Infrared Module and Optional USB	Free Samples
MAXQ622	16-Bit Microcontrollers with Infrared Module and Optional USB	Free Samples

More Information
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