AFE5832LP and AFE5832 Ultrasound Analog Front End for Ultra-Portable Applications

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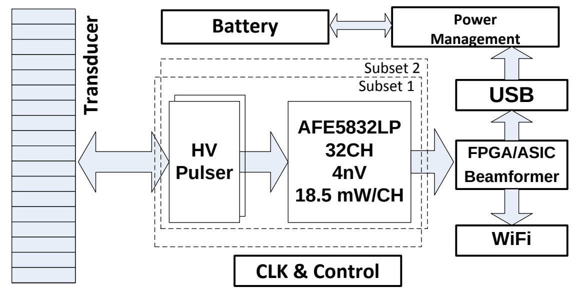
Introduction

In the past several years, multiple digital and wireless ultrasound probes have been introduced to physicians as vision-enhanced stethoscopes, which may someday replace the traditional 150-year-old stethoscope. GE's Vscan, Siemens' Freestyle, SonoSite's iViz and Philips' Lumilify are among the first wave of ultra-portable probes for physicians and rural villages. Ultrasound imaging may be the only modern imaging modality choice for rural areas because of its cost-effectiveness and portability. It is exciting to TIers to innovate and deliver solutions to serve people who may have never been served by modern medicine.

Further reducing power requirements and increasing image quality demands high channel count and low power ICs. The AFE5832LP and AFE5832 devices are designed to address these needs. The AFE5832 is industry's first 32-CH analog front-end (AFE) solution, and the AFE5832LP is its lower power version. Both devices are pin-to-pin compatible. The AFE5832LP achieves power consumption of < 20 mW/CH, which is approximately 6× lower than the power consumption of the AFE5818 and AFE5808 devices in traditional console systems.

System and Power Budget Analysis

Ultrasound probes are sealed by bio-safe materials. Heat generated by active internal electronics is dissipated through probe surfaces only, the area that touches patients or physicians. Thus, probe-surface temperature control is critical. A temperature greater than 45°C at probe surface will certainly cause discomfort to patients. To prevent this, many applications require an average power dissipation of 3 to 2.5 W. The in-probe electronics include transmitter, receiver, digital beamformer, data communication, and battery-power management. Typically one hour of continued operation is required. In some performance-driven ultra-portable systems, an average power of 4 W to 5 W is acceptable when larger probe size and active heat dissipation method are implemented.



Unlike traditional diagnostic radiology applications, wireless probe applications typically focus on basic evaluation of patients. These applications can be used, for example, to screen for organ dysfunction or performance of basic functional imaging. As a result, performance trade-offs may be made to improve ultra-portability. The AFE5832LP and AFE5832 implement novel low-power architectures. While the premium AFE5808A and AFE5818 family has 0.8-nV/rtHz input referred noise, the AFE5832LP relaxes it to 4nV/rtHz and achieves 6× lower power. The integrated digital time-gain-compensation (TGC) circuits not only reduce the overall system power consumption but also simplify the system design by eliminating external analog TGC control circuits. In addition, these wireless or digital probes do not have long cables between transducer and electronics; thus, image-quality reduction due to cable reflection is not a concern. The feature of active termination in premium AFEs has limited benefits for wireless probe or digital probe. The AFE5832LP-based systems achieved sufficient performance without the active termination feature.

Table 1. Device Comparison

DEVICE	POWER CONSUMPTION	NOISE	TGC CONTROL	ACTIVE TERMINATION
AFE5832LP	18.5 mW/CH at 20 MSPS	4 nV/rtHz	Internal Digital Engine	No
AFE5832	38 mW/CH at 20 MSPS	2.1 nV/rtHz	Internal Digital Engine	No
AFE5818	125 mW/CH at 20 MSPS	0.75 nV/rtHz	External Analog Circuit	Yes
AFE5808	129 mW/CH at 20 MSPS	0.75 nV/rtHz	External Analog Circuit	Yes

The most commonly used ultrasound probe frequencies are between 2.5 M and 10 MHz. Thus the ADC sampling frequency can be selected as 4×higher than the probe frequency, or 10 MSPS and 40 MSPS, respectively. The digital block of the device can combine the digitalized data from 2 to 4 analog channels into a single pair of LVDS outputs up to 1 Gbps, depending on the ADC sampling rate and resolution. The unused LVDS pairs can be powered down to maximize the LVDS efficiency.

Similar to other battery operated systems, operation duty cycle plays a critical role for power optimization. 30 frames per second are considered as real-time imaging. When a 128-element transducer is used, 128 image lines forms a frame of image. The capture time of each image line is about 200 µs, which corresponds to the imaging depth of 15 cm in the human body. Based on these, the active duration time is calculated:

$$0.2\ \text{ms} \times 128 \times 30 = 768\ \text{ms} \tag{1}$$

Equation 1 shows a duty cycle of 77%. When we reduce the depth of field, the frame rate, or image lines per frame, the duty cycle is reduced proportionally. The AFE devices support flexible power saving modes controlled by the external serial programming interface (SPI) or dedicated device pins. Wake-up time of the AFE devices can be as short as several microseconds, which can minimize the AFE active time and maximize battery life. Depending on the imaging quality and battery life trade-off, a typical duty cycle could be around 50% or even less. At 50% duty cycle, the AFE5832LP and AFE5832 devices in a 64-CH ultra-portable system consume only approximately 0.6 W and 1 W, respectively. The rest of the system, such as the transmitter, a FPGA- or ASIC-based 64-Ch true digital beamformer, WIFI module, etc. has a power budget of approximately 2 W. Considering an 85% to 90% efficency of the power-managment circuit, the total power consumption of the system can be below 3 W.

Table 2. Power Consumption Distribution

BLOCK	POWER CONSUMPTION
AFE5832LP	0.6 W
High voltage pulser	0.4 W
FPGA	1 W
WiFi and others	0.5 W

An appropriate duty cycle can be selected for optimizing the power during B-mode or color Doppler imaging. While continuous wave Doppler for blood flow measurement requires 100% duty cycle, in the CW mode, the AFE5832LP achieves 10 mW/CH, which is only 50% of regular B modes. As a result, power of the AFE devices remains at about 0.6 W.

As discussed early, the probe temperature is critical for patient comfort. The AFE devices integrate on-chip temperature sensors. System designers can calibrate the readout of the temperature sensors and create correlation curve between probe case temperature and the AFE's sensor readout.

Summary

TI's latest low-power 32-CH AFE5832LP and AFE5832 greatly simplify wireless or digital ultrasound probe design. The AFEs achieved low power by eliminating unnecessary premium features and simplifying external circuits. These AFEs make it possible to delivery ≥ 64-CH ultrasound systems to rural physicians and remote villages at a fraction of the price of traditional systems. We are motivated to see TI products improving health care for everyone. In addition, TI is committed to designing more innovative products to support AFE devices.

References

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TI Data Sheet *AFE5832LP 32-Channel Ultrasound AFE With 18.5-mW/Channel Power*

TI Data Sheet *AFE5832 32-Ch, Ultrasound AFE With 35-mW/Ch, 1.4-nV/√Hz Noise*