

An Inexpensive Altitude Deviation Alert

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Background

Altitude is most commonly measured by its non-linear relationship to air pressure (Figure 1). At sea level, air pressure is approximately 30 in. Hg (100 kPa), decreasing to approximately 13 in. Hg (45 kPa) at an altitude of 18,000 feet (5500 m). Traditionally altimetry is performed by mechanical means – a sealed air bellows is subject to atmospheric pressure; its dimensional changes are geared to move indicators on a mechanical display, or to operate a Gray-coded encoder wheel providing the information in electronic form. Cost and size limitations would not permit such a solution for this project; instead a monolithic piezoresistive pressure sensor was used. The device is comprised of a sealed vessel containing a known air pressure, one wall of which is a silicon die incorporating a micromachined strain gauge and amplification stage. The package design permits air pressure to be introduced to the other side of the die, causing it to deflect due to the pressure differential. A buffered voltage proportional to the pressure differential is provided as output.

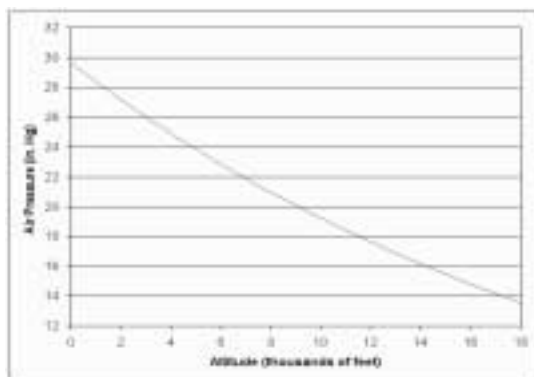


Figure 1

Our goal was to sound an alert upon a deviation as small as 100-200 feet. This required a resolution of 4 millivolts over a range of 2.3 volts, corresponding to an Analog-to-Digital Converter resolution of 10 bits, before allowing for granularity, hysteresis, or low-order-bit ADC noise. Ideally, a resolution of 13-14 bits would be needed to accomplish our goal.

Design Strategy

Our processor selection was the Atmel AVR at90s4433, chosen for size, cost, and low power consumption. The part includes an excellent low-power ADC, but with a resolution of only 10 bits. There are numerous serial ADC devices available in the market, but costs tend to rise above 10-12 bits. With cost, size, and power consumption all factors, we decided to re-examine our design requirements. In normal operation the voltage corresponding to the altitude

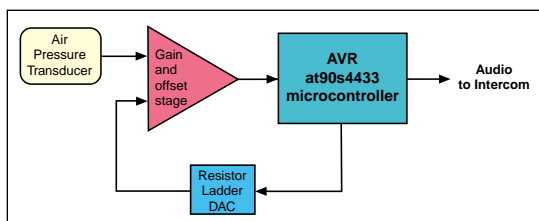


Figure 2

being measured is static, though it may be static at any point over a range of 2.3 to 4.6 volts. If the voltage were scaled to the point where the required 4 millivolt resolution were measurable with the AVR ADC, it would be out of range for other altitudes.

The problem was solved by implementing a 4-bit resistor ladder Digital to Analog Converter driven by the AVR controller. The output of this DAC was used to control the offset of the gain stage between the pressure sensor and the ADC. (Figure 2) This permitted a step selection to be made by the AVR firmware, insuring that the voltage being measured was within the ADC rails. Since only a delta measurement was being made, the DAC could be constructed with relatively low-precision resistors (1%). By choosing offset and gain stage values appropriately, the steps were overlapped, permitting any voltage over the input range to be offset to a point in the center 80% of the ADC range.

When a stable altitude is reached a button press initiates a search for the DAC output step that will cause the ADC input to fall near the center of its range. Based on the step selected, the firmware can compensate for the non-linearity of the relationship between altitude and air pressure. The deviation alert is generated both by LED indicator and an audio tone introduced into the aircraft intercom system. The tone is generated with one of the AVR programmable timers, with a second timer used for both system timing and control of the tone cadence. Different tones indicating climb, descent, return to proper altitude, and low battery (detected by another ADC channel) are generated while the processor spends approximately 99% of its time asleep, saving power.

The application firmware was developed using Atmel AVR Studio, the ICE200, and the Imagecraft AVR Compiler. The AVR's compiler-friendliness allowed the application to be implemented in C with code size being only a minor factor. Source-level debugging simplified the development effort and later bug fixes. During debugging, software state and ADC input values were reported to the AVR serial port, simplifying the development process.

A 0.050" (1.27 mm) PCB card-edge pattern was included in the PCB design for the AVR in-system programming connections. The connector also included power and ground connections, permitting one-step production programming of the AVR in-situ, without bed-of-nails ICT fixturing, and with zero additional component cost.

Conclusion

By re-examining our design goals, we were able to utilize the ADC in the at90s4433, where at first this did not seem possible. With the exception of a buffer, the AVR was the only digital part in our design, keeping both cost and size to a minimum. (PCB dimension was 2x2" (50x50 mm) including connectors and the pressure transducer) With a remaining code space of 50%, as well as a pin-compatible growth path in the Mega8, we have an ample growth path for new features. □

FOOTNOTES:

- 1- Several drawings of a conventional barometric altimeter have been made available at <http://www.4innovation.biz/altimeter>
- 2- Motorola MPX5100 series, http://www.motorola.com/webapp/sp/s/site/prod_summary.jsp?code=MPX5100&nodeId=01126990368716
- 3- Imagecraft, <http://www.imagecraft.com/software/devtools.html>

Overview

A complex and expensive regulatory approval process for avionics equipment in the US and other countries has created a market for accessories and devices that, since not connected directly to the aircraft, are exempt from the approval process. Such devices are expected to be substantially less expensive than panel-mounted equipment, yet the pilot-user's expectation of low cost is still accompanied by one for high reliability, ease of operation, and the small size expected of a portable device. Our challenge was to provide an altitude deviation alarm that would alert the pilot to an inadvertent climb or descent, possibly into restricted airspace. Given recent global events, such deviations are subject to quick and often extreme