Smart design saves power

Power consumption is a primary consideration in smart transmitter design. By **Tracey Johnson** and **Michal Brychta**.

Designing loop powered field instruments with a 4 to 20mA analogue output and a HART (Highway Addressable Remote Transducer) interface within the required power budget can be challenging.

Modern field instruments – smart transmitters – are intelligent microprocessor based devices that monitor process control variables (see fig 1). Such field devices are becoming increasingly intelligent, as more processing is distributed into the field domain. More intelligence and increased functionality and diagnostic capabilities heightens the challenge of developing a system which can operate effectively within the limited power available from the 4 to 20mA loop.

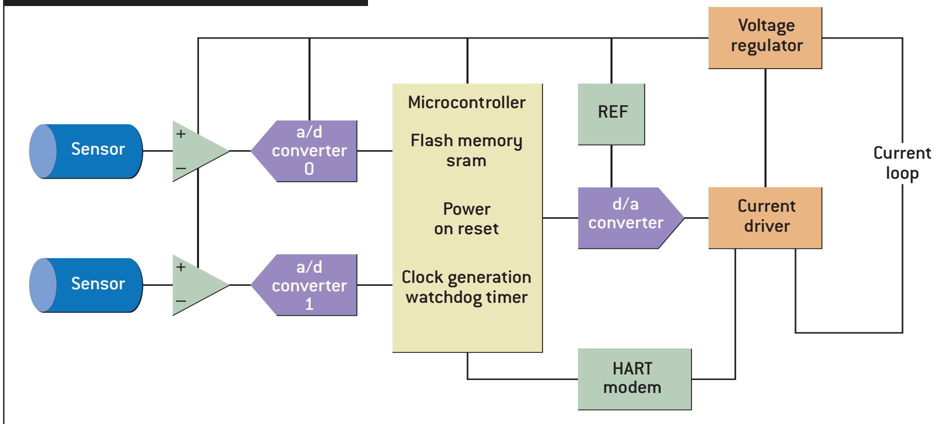
The most important element of any transmitter is the primary sensor and its optimum operation to deliver the most accurate representation of the environmental parameter being measured. The primary variable is often dependent on a secondary variable; for example, temperature compensation of a pressure sensor. In the example shown in Fig 2, the sensor is a resistive bridge with 5k impedance, operated by a continuous 3.3V excitation. This results in the sensor consuming 660μA of the overall system power budget.

The ADuCM360 analogue microcontroller integrates two low noise precision instrumentation amplifiers with programmable gain. The amplifiers are optimised for the lowest possible power and their stages are switched on only when needed for the required gain. This allows the best trade-off to be made between the circuit's performance and power requirements. In the sample circuit described here, the primary sensor could be used with only half the excitation voltage, resulting in half the signal level, and optimising the signal chain performance by doubling the amplifier gain programmatically from 16 to 32. This would save 330μA in sensor excitation current, but increase the amplifier supply current by 60μA – giving a net saving of 270μA. When considering such trade-offs, there are other aspects to consider, including the sensor signal to noise ratio during external electromagnetic disturbance. The fully integrated programmable solution can make evaluation of these options easier for the designer.

Two 24bit a/d converters sample the amplified primary and secondary sensor signals and translate them to the digital domain. In Fig 2, the converters are integrated on the ADuCM360 and again optimised for the lowest power needed for the required performance. The sigma-delta architecture offers inherent high resolution, linearity and precision, while the digital filter – which is always included in the sigma-delta a/d converter – allows programmable trade-offs between the required signal bandwidth and the input noise, the latter having a direct impact on the achievable resolution. Often, a resolution higher than 16bit is needed on the field instrument input in order to deliver 16bit resolution on its output.

A microcontroller is used for processing the inputs from all the field instrument sensors and for calculating the resulting value of the measured process variables. On top of that, the processor is required to perform more diagnostics as well as more complex communications. In this example, a 32bit ARM Cortex-M3 risc processor is used, complemented by 128kbyte of flash, 8kbyte of sram and other peripherals such as power on reset functionality, clock generation, digital interfaces and a range of

Fig 1: A smart transmitter signal chain

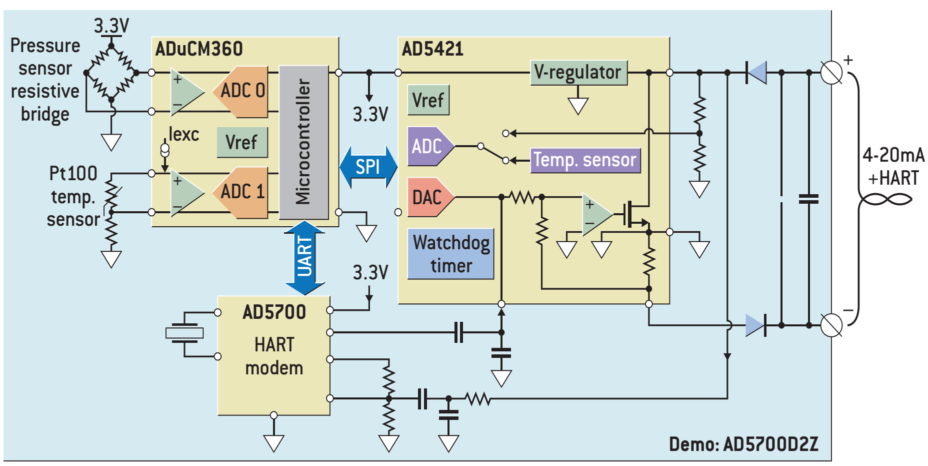


diagnostics features. The microcontroller is thus a complex component, with the potential to require a lot of power, so the more processing that can be done per every mW, the better.

An obvious trade-off is between the microcontroller core speed and the supply current. Less obviously, power can be saved by choosing the lowest necessary clock frequency for each digital peripheral, such as serial interfaces and timers. In this example, the fastest the 4 to 20mA output is updated is every 1ms. While the ADuCM360 allows the SPI interface to be clocked at a maximum of 16MHz, using a moderate 100kHz serial clock with optimum clock sub-dividers saves around 30μA on the chip itself. A few more milliamps are saved by lowering the dynamic currents related to the parasitic capacitance of the SPI signals on the pcb tracks and the component pin capacitances. The Cortex-M3 in the ADuCM360 consumes around 290μA/MHz. It includes flexible internal power management options, with the ability to switch power and clock speeds dynamically to the internal blocks, to allow the optimum system power versus performance balance.

The field instrument 4 to 20mA output current is set by a d/a converter followed by an output current driver. The AD5421 integrates the 16bit d/a converter and the current output stage, as well as a precision voltage reference. Also featured is programmable voltage regulation circuitry, to extract power from the loop to power both itself and the rest of the transmitter signal chain. The AD5421 provides a number of on-chip diagnostic features, all of which can be configured and read by the microcontroller, but can also operate autonomously. Even with such a high level of integration, the AD5421 draws a maximum of 300μA and has a total unadjusted error specification over temperature of less than ±0.05% FSR. This maximises the granularity and accuracy of the communicated measurement without affecting system power consumption adversely.

Fig 2: Block diagram of a demonstration HART enabled field instrument



Finally, complementing the 4 to 20mA analogue output, a HART modem provides digital communication with the host. HART communication allows the implementation of features unthinkable with analogue only communication. Examples include the host retrieving the instrument's secondary variables, diagnostics information or performing remote calibration routines. Low power and small footprint are important considerations when designing the HART circuit.

With typical transmit and receive currents of 124μA and 86μA respectively, the AD5700 will not contribute significantly to the overall instrument current budget. The HART output modulates the output current and is interfaced via a dedicated pin to the internal summing node inside the AD5421. The HART input is coupled from the current loop via a simple passive RC filter. The filter works as the first stage bandpass filter for the HART demodulator and improves the system electromagnetic immunity, important in harsh environments. The clock for the HART modem is generated by the on-chip low power oscillator with a 3.8664 MHz external crystal with two 8.2pF capacitors to ground, connected directly to the XTAL pins. This configuration uses the least possible power.

In conclusion, not only does this solution deliver on low power, but it is also a high performance solution, with minimum area overhead, not to mention HART compliance.

The high level of integration in the ADuCM360 enables flexibility and shifts the focus from traditional discrete component designs to the optimum use of each integrated block within the chip. The system designer can explore the trade-offs, even at late stages of a design, by simply changing the circuit setup in the software. This allows for short design cycles, ease of circuit modifications and tuning of circuit performance, without the need to go through costly and time consuming pcb revisions.

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