Electromagnetic Flow Meters: Design Considerations and Solutions

By Colm Slattery and Ke Li

Where Are Flow Meters Used in Industry Today?

"If you can't measure it, you can't manage it." An often heard quote in industry and particularly relevant to flow measurement. Simply stated, there is an increasing need to monitor more flow and often with more speed and accuracy. There are a few areas where industrial flow measurement is important, such as residential waste. With more and more focus on protecting our environment, the disposal and monitoring of waste is critical as we strive to create a cleaner and less polluted world. Humans are consuming vast quantities of water and this will continue as the world population grows. Flow meters are critical in both monitoring the residential effluent waste as well as being an integral part of the process control system in wastewater treatment plants.

Flow meters also find homes in many industrial control processes, including chemical/pharma, food and beverage, and pulp and paper. Such applications often have the need to measure flow in the presence of high levels of solids—not easily achieved by most flow technologies.

High end flow meters are needed in the area of custody transfer, which deals with the transfer and payment of a product transfer between two parties. An example would be oil transfer through a large pipeline. Here, even a small change in the accuracy of the flow measurement over time can result in significant revenue lost or gained for one of the parties.

Why Is Electromagnetic Induction Technology a Good Fit for Liquid Flow Measurement?

This technology has a number of advantages when it comes to liquid flow measurement. The sensors are generally inserted in line into the pipes' diameter, and are therefore designed such that they do not disturb or restrict the flow of the medium under measurement. As the sensors are not directly immersed in the liquid—there are no moving parts—there are no wear and tear concerns.

The electromagnetic method measures the volume flow, which means the measurement is insensitive to changes in effects such as fluid density, temperature, pressure, and viscosity. Once the electromagnetic flow meter is calibrated with water, it can be used to measure the other types of conductive fluid—with no additional correction. This is a significant advantage that other types of flow meters don't have.

Electromagnetic technology is particularly suitable for measuring within a solid-liquid two-phase medium, such as a liquid with suspended dirt, solid particles, fibers, or viscosity within a heavily conductive medium such as slurry. It can be used to measure the sewage, mud, ore pulp, paper pulp, chemical fiber slurry, and other media. This makes it particularly suitable, for example, to the food and pharmaceutical industry, where it can measure the flow of corn syrup, fruit juice, wine, medicine and blood plasma, and many other special media.

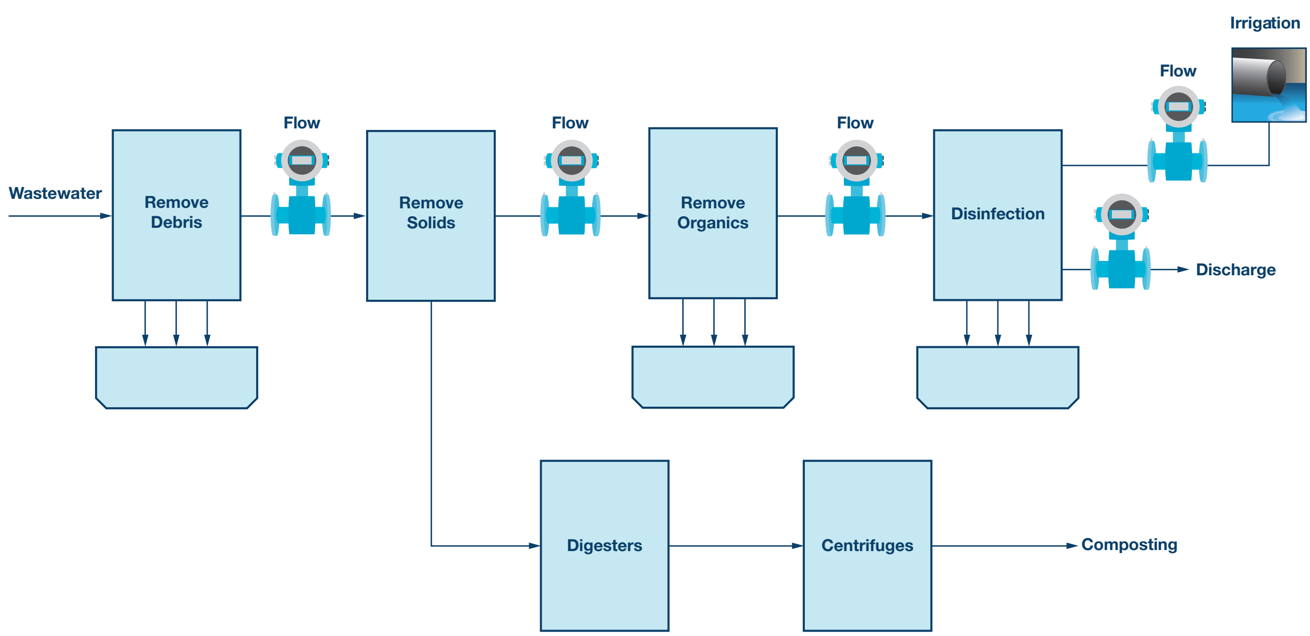

Figure 1. Simplified wastewater treatment plant.

How Does the Technology Work?

The working principle of a magnetic flow meter is based on Faraday's law of electromagnetic induction. According to Faraday's law, when the conductive fluid flows through a magnetic field of the sensor, an electromotive force proportional to the volume flow is generated between the pair of electrodes, which is perpendicular to the flow direction and the magnetic field. The amplitude of the electromotive force can be expressed as:

$$E = kBDv$$

Where E is the induced electric potential, k is a constant, B is the magnetic flux density, D is the inner diameter of the measuring tube, and v is the average velocity of the fluid in the axial direction of the electrode cross-section inside the measuring tube.

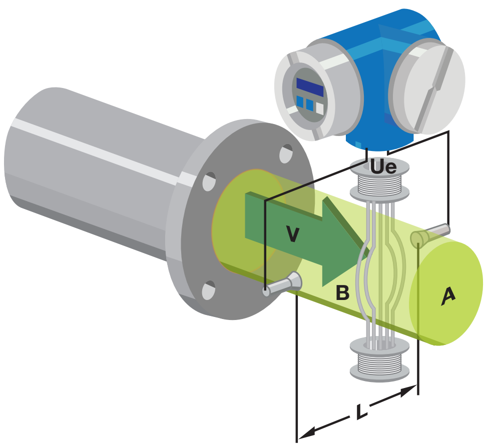

Figure 2. Working principle of the magnetic flow meter.

What is the Output Range of the Sensor?

The sensor has a differential output. Its sensitivity is typically 150 microvolts/(mps) to 200 microvolts/(mps). Since the excitation current alternates its direction, the sensor output signal amplitude doubles. For the flow rate measurement range of 0.5 meters/second to 15 meters/second, the sensor output signal amplitude ranges from 75 microvolts to approximately 4 mV to 6 mV. Figure 3 shows the sensor output signal when being excited with constant current source and with fluid flowing through the sensor. The scope plot captured on the sensor output leads shows a very low level signal sitting on significant common-mode voltage. The purple trace is for the positive electrode and the red trace is for the negative electrode. The pink trace is the math channel that subtracts the positive and negative electrodes. The low level signal sits in the significant common mode.

What Is the Traditional Approach to Measuring the Sensor?

The traditional approach has been very much an analog one—a preamplifier stage with a high input impedance to mitigate against sensor leakage effects and with high input common-mode rejection, followed by a 3rd or 4th order analog band-pass filter, a sample-and-hold stage, and finally an analog-to-digital conversion. A typical analog front-end approach is shown in Figure 4. The sensor output signal is firstly amplified by an instrumentation amplifier. It is crucial to amplify the interested signal as much as possible, but also to avoid the amplifier output saturation by the unwanted dc common-mode voltage. This usually limits the gain of the first stage instrumentation amplifier to no more than ×10. A band-pass filter stage further removes dc effects and reamplifies the signal into to a sample-and-hold circuit—it is this difference signal, representing flow rate—that is then sent to an analog-to-digital converter.

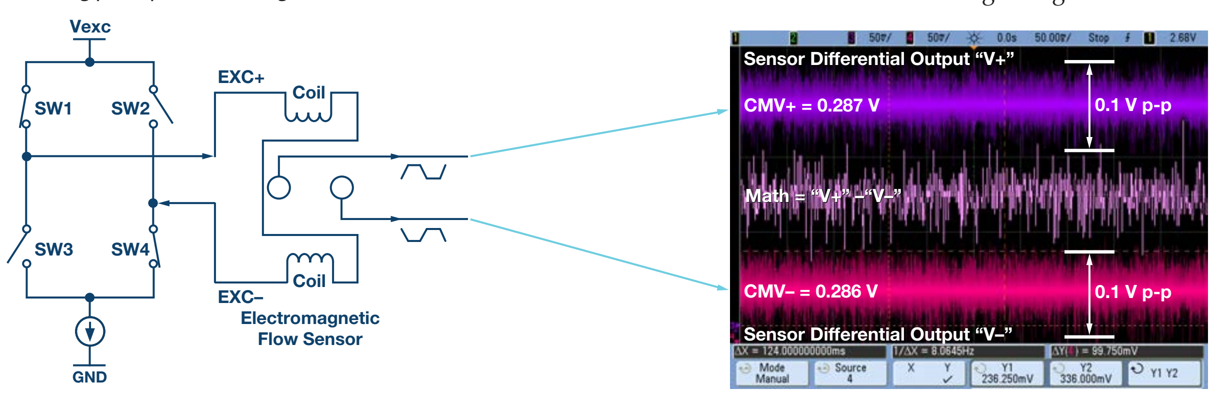

Figure 3. Output signal of electromagnetic flow sensor.

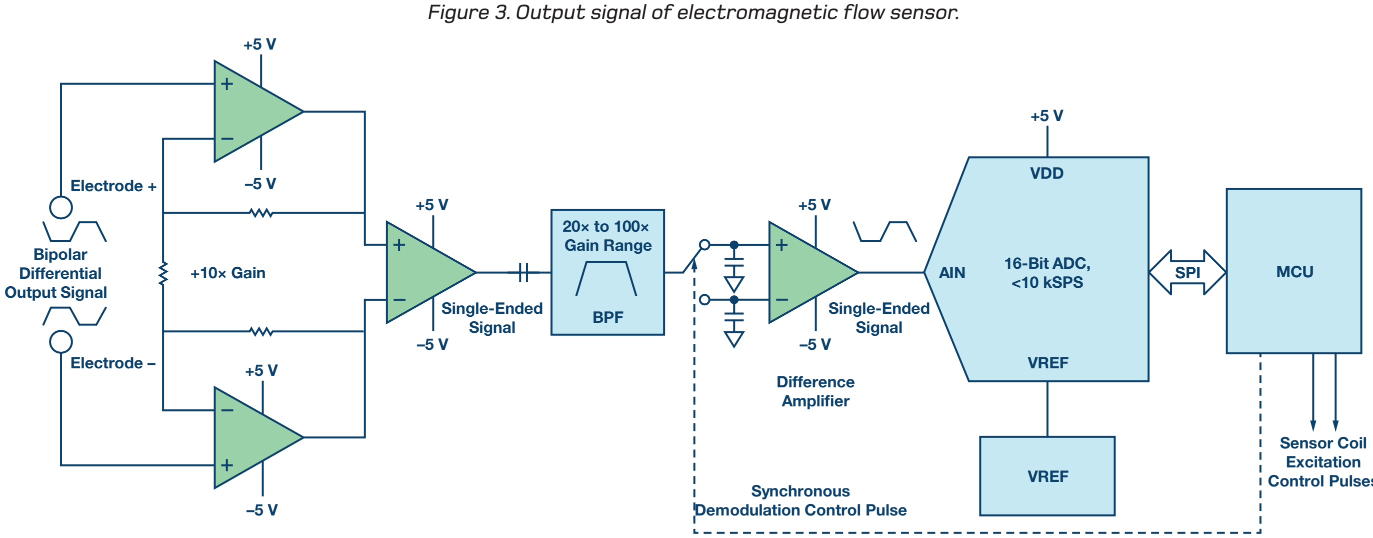

Figure 4. Traditional analog front end approach.

What Are the Trends in the Market That Are Influencing Changes in the Electromagnetic Flow Meter Architecture?

There are multiple industry trends driving the need for a new architecture. One is the ever increasing need for more data. The ability to monitor other attributes in liquid other than flow is becoming more and more valuable. This may be, for example, to determine what contaminants may be in the liquid, or it may be to determine whether the liquid has the correct density/viscosity for the application. There are many such requirements and benefits of adding such diagnostics. It is not possible with the traditional analog approach to extract such information easily as most of the sensor information is lost during the synchronous demodulation phase.

There is also a continuing demand for increased productivity and efficiency in the manufacturing process. In a liquid dosing/filling application, for example, more and more filling nodes are being added, and as manufacturing processes scale, and the speed of the filling increases, this drives the need for faster and more accurate flow monitoring.

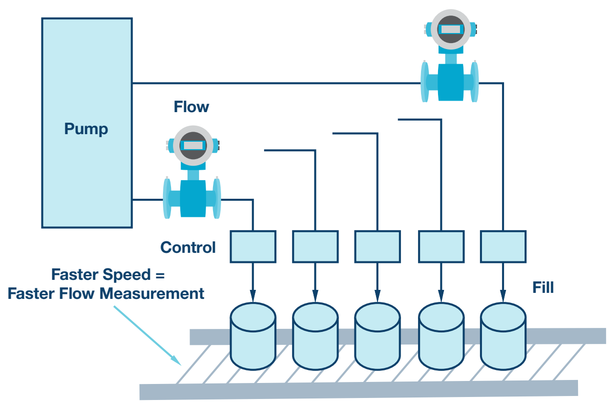

Figure 5. Liquid dosing/filling.

Traditionally, mechanical or weight technology has been used to determine the right amounts of liquid to add as part of either the dosing process or to determine exact fill amounts as part of the production process. These tend to be quite expensive and are difficult to scale. To meet this demand, flow meters, and EM flow in particular where liquids are concerned, have become the technology of choice.

What Does the New Architecture Look Like?

The oversampled approach greatly simplifies analog front-end design. The analog band-pass filter and the sample-and-hold stages can be removed. The front-end amplifier in the circuit now consists of only the one stage instrumentation amplifier—in our case, the AD8220 JFET input stage rail-to-rail output instrumentation amplifier, which can be directly connected to a high speed Σ-Δ converter.

What Is Important to the Analog Front End and How Does That Influence My Design?

The amplifier and the ADC are two of the most critical blocks in this application. The first stage amplifier has a number of key requirements.

One requirement is the common-mode rejection ratio (CMRR). The ions in the liquid electrolyte make directional movement, so electrical potential is developed between the electrodes and the fluid, which is what we call polarization. The electrical potential on the electrodes should equal each other if both electrodes are perfectly matched. The polarization voltages for different metals range from a few hundred mV to ±2 V. This is the dc common-mode voltage appearing at the sensor output and the input of the preamplifier. The preamplifier is key in rejecting this common mode.

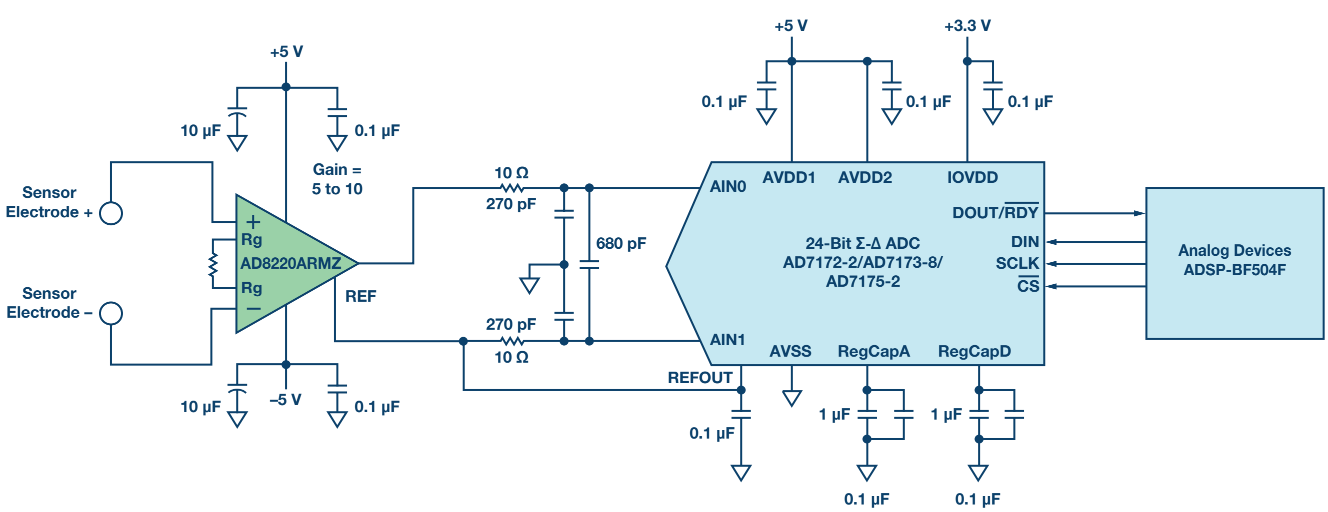

Figure 6. Oversampling architecture analog front-end with AD8220 and AD717x-x.

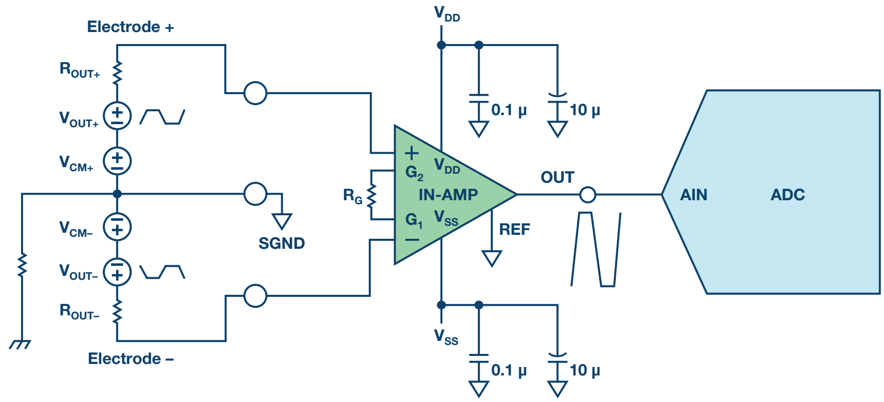

Figure 7. Common mode rejected by the preamplifier.

Table 1. Effects of Common-Mode Rejection on Actual Flow Rate

	CMRR vs. CMV DC and Noise After Rejection			
Common-Mode Rejection Ratio	120 dB	100 dB	80 dB	60 dB
0.28 V_{DC} Common-Mode	0.28 µV	2.8 µV	28 µV	280 µV
0.1 V Common-Mode Noise	0.1 µV	1 µV	10 µV	100 µV
Common-Mode Noise Translated into the Flow Rate of a 175 µV/(mps) Sensor	0.0006 mps	0.006 mps	0.06 mps	0.6 mps

Table 2. Effects of Amplifier Input Impedance on Flow Rate

Sensor Output Impedance (GΩ)	Amplifier Input Impedance (GΩ)	Reduced Signal Amplitude for 1 mps (µV)	Repeatability (%)	Error of Reading (%)
10	10	87.50	0.065%	0.196%
10	100	15.91	0.051%	0.154%
10	1000	1.73	0.049%	0.148%
10	10,000	0.17	0.049%	0.147%

A 100 dB CMRR would attenuate the 0.3 V_{DC} common mode to 3 µV, which is presented as a dc offset on the amplifier output that can subsequently be calibrated out. In an ideal scenario the common-mode voltage on the sensor would remain constant, but in reality it will change over time and be influenced by other effects such as liquid quality or temperature. The higher the CMRR, the better it will reduce the need for continuous background calibration and improve flow stability.

The metal material of the electrodes contact the electrolyte liquid. The frictions between the liquid electrolyte and the electrodes create ac common-mode voltages in higher frequencies. Though usually in smaller amplitudes, the ac common mode appears as a noise that is totally random, thus is more difficult to reject. This requires the preamplifier to have good CMRR not only on the dc range, but also in higher frequencies. AD8220 amplifier has excellent CMRR from dc to 5 kHz. For the AD8220 B grade, the minimum CMRR is 100 dB on dc to 60 Hz, and 90 dB up to 5 kHz, which rejects the common-mode voltage and noise to well around microvolt. With 120 dB CMRR, the 0.1 V p-p is reduced to 0.1 µV p-p. Table 2 shows the effect of poor CMRR rejection on the output sensor signal.

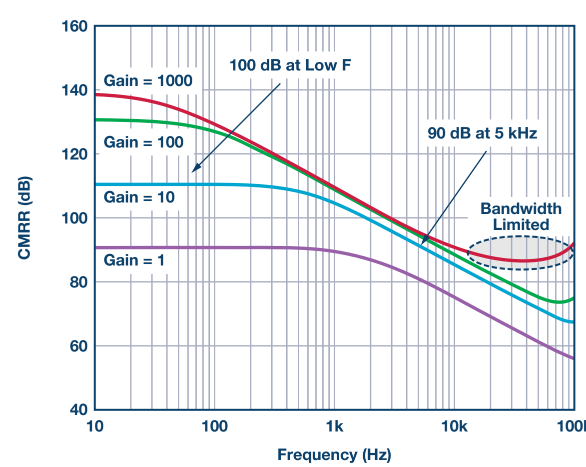

Figure 8. AD8220 dc and ac rejection of common-mode effects.

The low leakage current and high input impedance of the preamplifier stage is another critical parameter because the output impedance of the electromagnetic flow sensor could be as high as GΩ. High input impedance of the amplifier can avoid loading the sensor output too much that results in a reduced the signal amplitude. The amplifier should have the leakage current low enough so that they won't become a notable error source when flowing through the sensor. The 10 pA maximum input bias current and 1013 Ω input impedance of AD8220 make the part capable of dealing with a wide range of output characteristics for electromagnetic flow sensors. Table 2 lists what impact the preamplifier's input impedance has to a high output impedance sensor of 10 GΩ.

Finally, the 1/f noise on the range of 0.1 Hz to 10 Hz sets the noise floor for the application. When configured to a gain of 10 the referred-to-input voltage noise of AD8220 is about 0.94 μV p-p, which resolves 6 mm/sec instantaneous and the sub-mms accumulative flow rate.

How Do I Choose My ADC and What Is Important Here in the Application?

The oversampling approach does bring challenges and pushes the performance requirement of the ADC block. With no secondary analog filter active gain stage, only a small portion of the ADC input range is used. Oversampling and averaging itself does not allow for dramatically increased performance as each sensor cycle needs to fully settle to be used for a flow calculation. Further, you need enough analog-to-digital samples from these limited data points to remove unexpected glitches as part of the firmware process.

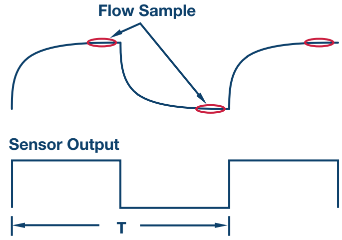

Figure 9. Flow signal sampling.

The oversampling architecture generally requires an ADC rate of >20 kSPS data rate—though the faster the better. This is not specifically related to the actual flow measurement. As there is no analog band-pass filter stage the raw sensor output is effectively seen by the ADC input. In this case, as the sensor's rising edges are not filtered the ADC needs to have enough resolution during the rising and falling edges to capture these edges accurately enough.

The flow meter's accuracy itself can be determined as either an instantaneous flow measurement or an accumulative flow measurement. The flow meter standard uses the accumulative flow technique—measuring the average flow of a volume of water over a long period of time, say for 30 or 60 seconds. This, rather than the instantaneous flow measurement determines the ±0.2% system accuracy. The instantaneous flow is applicable to the occasions where the real-time flow rate is important. It demands much higher levels of accuracies from the electronics. In theory, to resolve to 5 mm/sec instantaneous flow resolution the ADC will need to achieve 20.7-bit p-p resolution during one excitation period—a post-FIR filter of approximately 600 samples. This can be achieved by the analog front end.

The AD7172-2 provides the perfect combination of low input noise and high speed sampling for Electromagnetic flow applications. The typical noise of AD7172-2 with 2.5 V external reference can be as low as 0.47μV p-p. This means the final flow results can be refreshed at up to 50 SPS without the addition of extra amplification stages. Figure 10 shows the noise plots of the oversampling front-end circuit with AD7172-2.

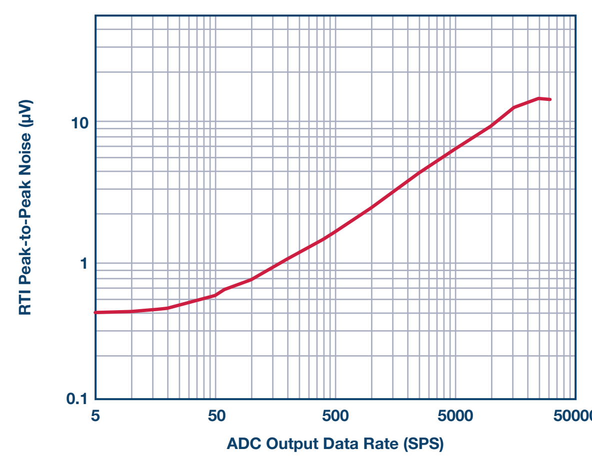

Figure 10. Test results of referred-to-input noise for oversampling architecture with AD8220 and AD7172-2.

Table 3. Noise Budget for an Analog Front End and ADC

Flow Rate Resolution for Sensor of 175 μV/(mps) Sensitivity	Signal Amplitude of Sensor Output at the Resolution	Budget for Referred-to-Input Noise of Analog Front-End	ADC Noise Budget at 10 Gain of Oversampling Analog Front End
10 mm/sec	3.5 μV p-p	1.75 μV p-p	5.8 μV p-p/19.7 bit*
5.4 mm/sec	1.89 μV p-p	0.95 μV p-p	3.2 μV p-p/20.6 bit*
5 mm/sec	1.75 μV p-p	0.88 μV p-p	2.9 μV p-p /20.7 bit*

*Data from one FIR filter cycle and one instantaneous flow calculation.

Table 4. Comparison of Measurement Accuracy Over Sensor Excitation Frequency

Excitation Frequency(Hz)	6.25	12.5	25	50	100	200	400
With AD7172-2	0.12%	0.12%	0.13%	0.16%	0.19%	0.24%	0.33%
With Closest Competition	0.13%	0.15%	0.19%	0.25%	0.33%	0.46%	0.64%
Gap	12%	22%	47%	57%	77%	89%	95%

How Can We Get Faster Response to Meet Industry Needs for Higher Efficiency?

It's possible to increase the system update rates of the flow measurement by increasing the sensor excitation frequency. In this condition, there is less time when the sensor output is *settled*, and therefore less available samples to average. With an ADC of lower noise, the referred to sensor output noise can further reduced. Using the same front-end driver, AD8220, configured in a gain ×10, the analog front-end performance can be benchmarked against the leading competition at higher update rates. Table 4 and Figure 11 show ADI's advantage gained at higher system update rates vs. the closest competitor.

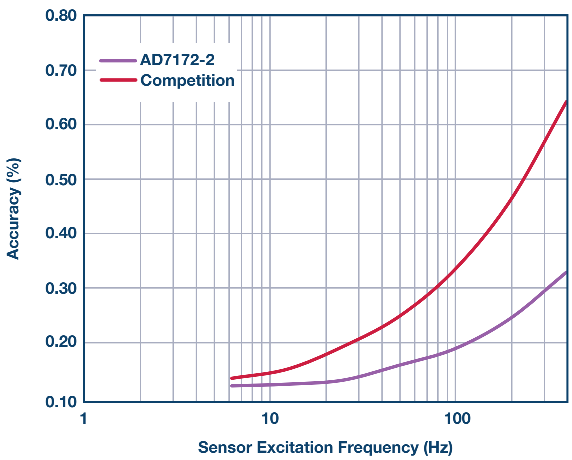

Figure 11. Comparison of measurement accuracy over sensor excitation frequency.

Will the In-Amp Be Able to Directly Drive the ADC and How Can I Be Sure of This?

Generally, this depends on the driving capability of the in-amp and the ADC's input structure. Many modern precision ADCs are based on a switched-capacitor architecture. The on-chip track-and-hold appears as a transient load to the upstream amplifier that it must be able to settle the switched-capacitor inputs to allow for accurate sampling.

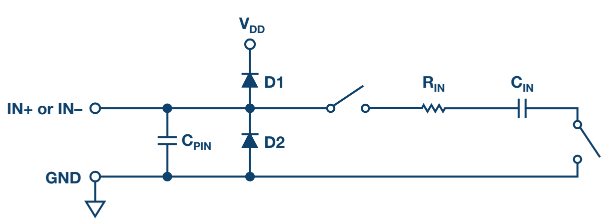

Figure 12. Equivalent analog input circuit.

The following equation can be used to check if the amplifier is to drive the ADC.

$$BW = 1/(2\pi \times (1/(2 \times MCLK) - T)) \times \ln [(FS - CMV)/(FS \times Error)]$$

Where:

BW is the minimum bandwidth required for the amplifier to drive the ADC.

MCLK is the ADC modulator clock frequency, Hertz.

T is the shorting phase time, seconds.

FS is the ADC full analog input range, volts.

CMV is the common-mode voltage of the ADC input range, volts.

Error is the settling error for the ADC sampling.

The AD7172-2, for example, has a modulator frequency of 2 MHz, the shorting phase time is 10 ns, the full input range is 5 V, the CMV is 2.5 V, and a settling error of 1 ppm. The resulting BW figure is 8.7 MHz, which would be required for the driver amplifier when AD7172-2 is in the unbuffered mode. This exceeds 1.7 MHz—the gain-bandwidth product capability of the AD8220 as well as many precision instrumentation amplifiers. The AD7172-2 has true rail-to-rail, integrated, precision unity-gain buffers on both ADC analog inputs. It is designed to drive the AD7172 input stage across all frequencies, and reduces the design complexity and risk for our customers. The buffers provide high input impedance with only 5 nA typical input current, allowing high impedance sources to be connected directly to the analog inputs. The buffers fully drive the internal ADC switch capacitor sampling network, simplifying the analog front-end circuit requirements while consuming a very efficient 0.87 mA typical per buffer. Each analog input buffer amplifier is fully chopped, meaning that it minimizes the offset error drift and 1/f noise of the buffer.

How Is the Magnetic Field Generated?

The magnetic field inside the measurement pipe is generated by applying the constant current through the coils that are installed next to the outside the pipe. The coils often exist in pairs and are connected in series to each other. The coils are usually hundreds of turns of copper wire and thus are seen as a significant inductance load by its driver circuit. The coil inductances are typically around tens of to hundreds of millihenry plus 50 Ω to 100 Ω dc series resistance. The magnetic field alternates its direction within each cycle when the driver circuit changes the direction of the excitation current, which is done by turning on and off the different pair of switches on the H-bridge. The alternating frequency is generally an integer fraction multiple of the power-line frequency for noise cancelation. The driver circuit consists of a constant current source and an H-bridge under the control of the microprocessor.

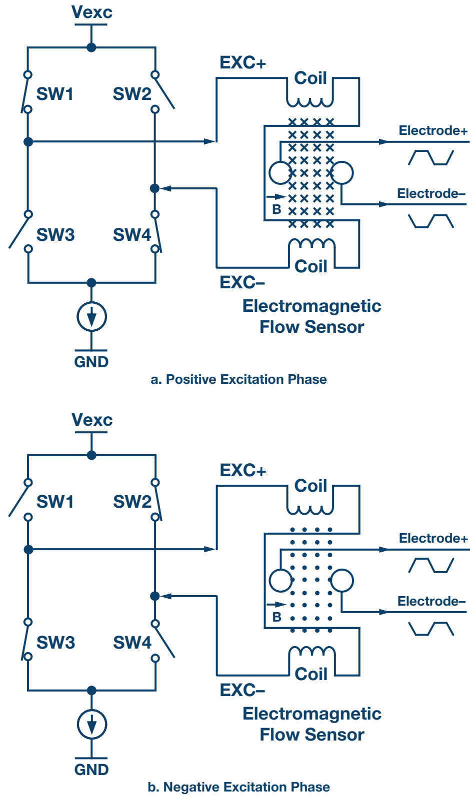

Figure 13. Magnetic field generation.

Is Power Dissipation Important?

Yes. The excitation currents for electromagnetic flow meters can be quite large, from up to 50 mA for smaller diameters up to 500 mA or 1 A for larger diameter pipes. The constant current circuit can consume significant amount of power and board area when it's linearly regulated.

A switch-mode power supply can be used to save the power dissipated compared to the linear regulated constant current circuit. As shown in the diagram, ADP2441 is configured in the constant current source output mode. The 1.2 V ADR5040 output voltage is divided by two resistors to 150 mV. This 150 mV voltage is applied to the ADP2441 voltage track pin so that voltage feedback pin also be kept to 150 mV. When putting a 0.6 Ω current set resistor at the feedback pin, the ADP2441 will adjust its output current to its I_{SET} level. By adjusting the value of the current setting resistor connected to ADP2441 feedback pin, the constant current source can be tuned.

Table 5. Recommended Switching Regulators

Recommended ADI Switching Regulators	Efficiency
ADP2441	90% at 200 mA output (@12 V), up to 1 A capable
ADP2360	90% at 10 mA output, up to 50 mA capable

Are There Any Other Benefits of this Drive Stage Design?

There are significant area benefits. Electromagnetic flow sensor driver circuits, also called excitation circuitry, are usually isolated from the signal conditioning circuit—1 kV basic isolation typically suffices. Conventional electromagnetic flow transmitters commonly use optical coupler isolation. Optocouplers tend to have poor reliability and are quite large. The ADuM7440 digital isolator combines high speed CMOS and monolithic air core transformer technology, providing four independent isolation channels in a small, 16-lead QSOP package.

Compared with the conventional scheme using an optical coupler, linear regulated constant current source, and discrete FET H-bridge in through-hole package, the power savings using the digital isolation approach could save more than 80% of the circuit area.

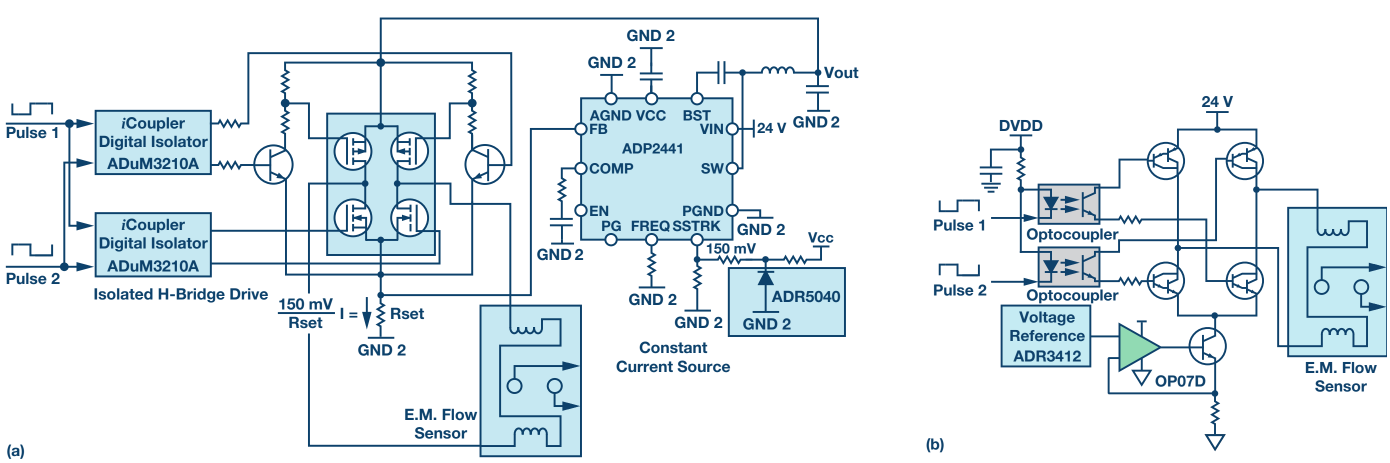

Figure 14 (a). Drive isolated H-bridge with SMPS and iCoupler®.
(b). Drive isolated H-bridge with linear regulated current source and optocoupler.

How Is Flow Rate Calculated?

In the digital domain, the ac flow signal will still need filtering and synchronous demodulation. Figure 15 illustrates how the algorithm implements the synchronous demodulation in the digital domain. A DSP issues Control Signal 1 and 2, a pair of complementary logic signals for the electromagnetic flow sensor coil excitation. Under the control of these two signals, the current flowing through the electromagnetic flow sensor coil reverses in each cycle—thus the direction of the magnetic field and therefore the sensor output on the electrodes also reverses in each cycle too.

Table 6. Key Component Comparison Used During the H-Bridge Drive Stage

Components	Qty	Package	Area (mm²)
PC817B	2	DIP-4	63.24
TIP127, PNP Darlington	2	TO-220	51.54
TIP22, NPN Darlington	2	TO-220	51.54
Total Area			333

Components	Qty	Package	Area (mm²)
ADUM7440ARQZ	1	QSOP-16	31
ZXMHC6A07N8	1	SOIC-8	31
MMBT3904LT1G	2	SOT-23	13.92
1SMA5917BT3G	1	SMA	13.55
Total Area			89

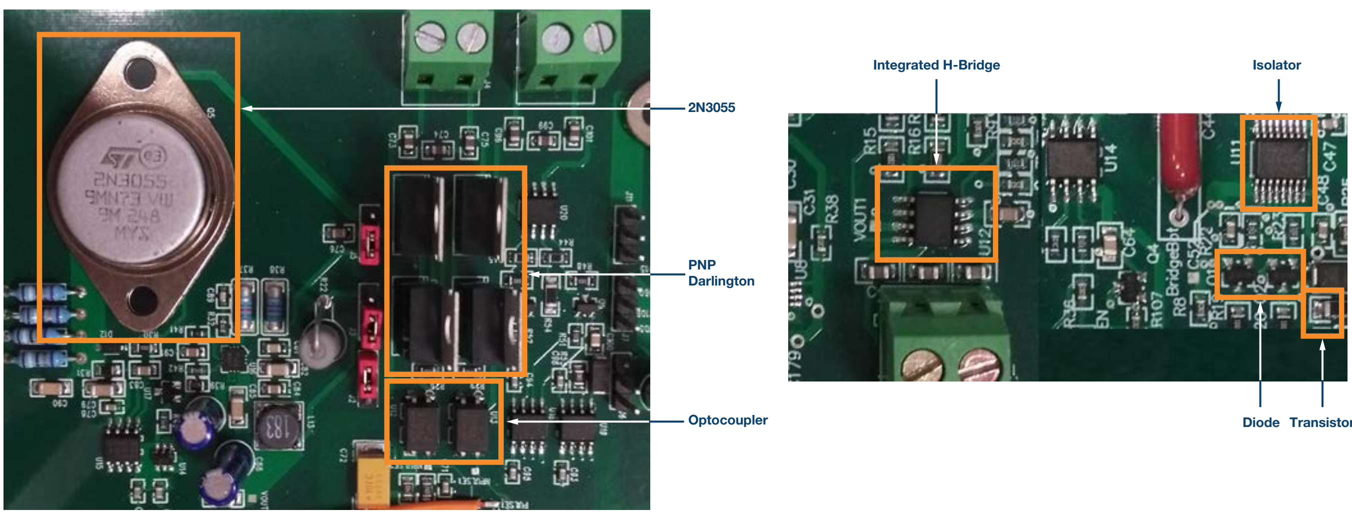

Figure 15. Area comparison of optocouplers vs. digital isolator design.

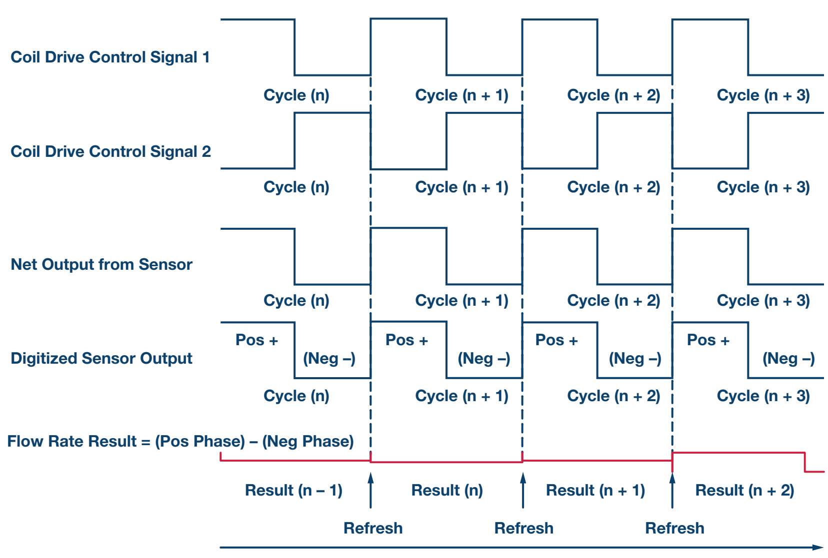

Figure 16. Synchronous demodulation and flow rate calculation in digital domain.

In the nth cycle, for example, the DSP (in our case, ADSP-BF504F) knows the timing and logic of Control Signal 1 and 2 when the ADC samples are coming in. This allows the DSP to sort these ADC samples in accordance with the logic status of the coil driving control signals into two arrays in the SRAM. That is, those time-stamped samples that are obtained during the positive half cycle are sorted into one group and those samples that are acquired in the negative half cycle are sorted into another group. Each set is subsequently passed through an FIR (finite impulse response) low-pass filter. The filter's cutoff frequency is set at 30 Hz, allowing the useful signal to pass rejecting the interferences of the power line frequency and high frequency noise components. Figure 17 shows the profile of the FIR filter in the oversampling front-end design and that of the analog band-pass filter, which was used in the analog synchronous demodulation architecture.

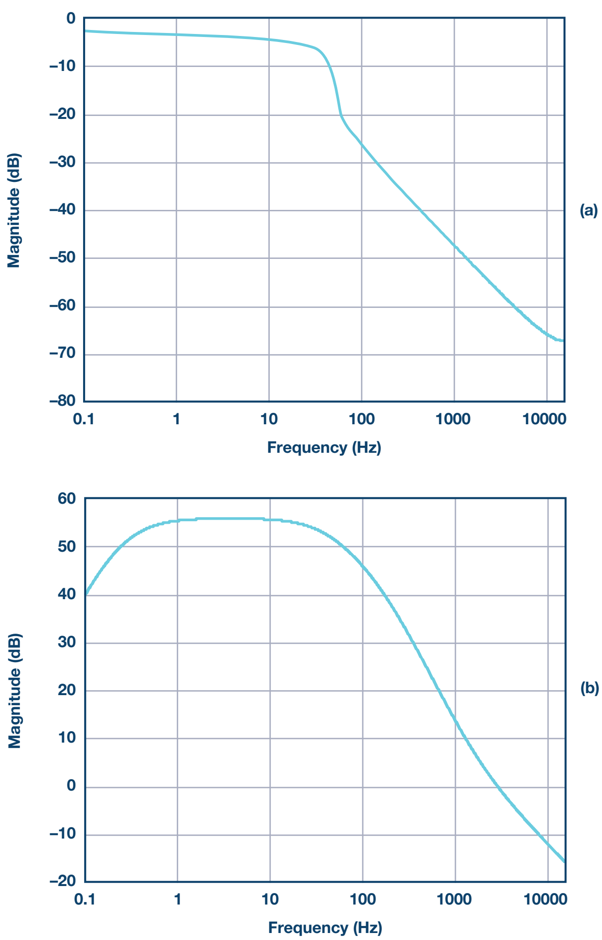

Figure 17 (a). Profile of a digital FIR low-pass filter.
(b). Profile of an analog band-pass filter.

The algorithm then subtracts the two averages to get a value that is proportional to the flow rate. The resulting unit for this value is LSB per (meter/sec). This value needs to be further processed. The final flow rate computation is:

$$\text{FlowRate (mps)} = \frac{\Delta FlowRate \times V_{REF}}{(2^N - 1) \times G \times Sensitivity} \times K_T \times K_S - K_Z$$

Where:

$\Delta FlowRate$ is the subtraction result of the two averages from the positive and negative excitation phases, LSB.

V_{REF} is the ADC reference voltage,volts.

N is the number of ADC resolution bits.

G is the gain of the analog front end.

Sensitivity is the nominal sensitivity of the sensor, V per (meter/second).

K_T is the transmitter coefficient.

K_S is the sensor coefficient.

K_Z is the zero offset.

How Do I Choose the Right Processor?

The choice of process is an important one. Increasingly, there is a need for more processing capability, either to support more complex algorithm computations or for enhanced diagnostics or prognostics. There is also global movement to drive greater energy efficiency across electrical and industrial infrastructure. Customers are demanding more processing capability at lower power and at attainable cost points.

The digital filter for EM flow can demand a large amount of processing power. The 32-bit FIR filter used consumes 80 MIPS. The flow rate computation, the periphery communications driver, and data communication take 40 MIPS, 32 MIPS, and 20 MIPS, respectively. These add up to 172 MIPS in total. In this design the above tasks are done by an ADSP-BF504F digital signal processor of up to 400 MIPS capability. Already, nearly 50% of the processing capability has been used and this is before multilayer communication stacks, HART communications, diagnostics, safety monitoring functions, or LCM drivers have been included.

Table 7. MIPS Consumption

Task	MIPS
FIR Filter	80
Metering Data Processing	40
AD7172-2 Data Access	32
Others	20
Total	172

The on-chip peripherals are also key. The DSP has a variety of functions to implement, including SPI, UART, I²C, and pulsed output communications. There are 35 GPIOs available for the hardware control and logic input/output that are, for example, for controlling the LCD, keypad input, alarms, and diagnostics. The SRAM memory stores the filter coefficient, SPI data communication, LCM data cache, and machine state data, and internal status flags. The 68 kB on-chip static random access memory (SRAM) meets system-level requirements and consists of a 32 kB L1 instruction SRAM/cache and a 32 kB L1 data SRAM/cache. The memory is also needed for RS-485 and HART communication. 4 MB on-chip flash memory of ADSP-BF504F can be used to store the data for the program, the filter coefficients, and calibration parameters.

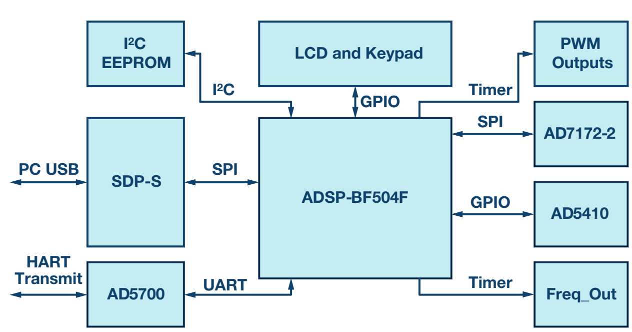

Figure 18. ADSP-BF504F peripheries.

Going forward, there will continue to be a push for more and more processing power. To meet this increased demand, the ADSP-BF70x Blackfin® processor series is a high performance DSP that delivers a class-leading 800 MMACS of processing power at less than 100 mW. The cost-effective eight member series includes up to 1 MB of internal L2 SRAM, eliminating external memory in many applications, while a second configuration features an optional DDR2/LPDDR memory interface. Table 8 shows the key features of the ADSP-BF7xx family.

What Does ADI Offer for Electromagnetic Flowmeter Solutions?

ADI has developed a system-level reference design to prototype the complete signal chain for an electromagnetic flow meter. The system is configured so that it can connect to any EM flow sensor type, apply the appropriate excitation frequency and voltage levels to generate the magnetic field (controlled by a Blackfin DSP), measure the sensor output, and apply postprocessing filters and algorithms to calculate flow rates. ADI calibrated the design in a real flow rig environment, shown in Figure 19, and stored calibration coefficients in memory. Single point or multipoint calibration is possible, allowing for an increased performance through multipoint linearization. In doing this, we were able to demonstrate that the performance of the analog front-end design can meet that of leading high end flow meters.

There are some key advantages of the oversampled architecture compared to the traditional architecture. There are significant area and cost savings—up to 50% and 20%, respectively. There are also power savings and enhanced system performance benefits due to the ability to save the sensor signal and apply postprocessing to it. For more information on ADI reference design, please contact cic@analog.com.

Table 8. ADSP-BF70x Blackfin Processor Family

Generic Device	DSP Core Performance	On-Chip Memory	External Memory	Key Connectivity Options	Other Features	Package
ADSP-BF700 ADSP-BF702 ADSP-BF704 ADSP-BF706	100 MHz to 400 MHz 800 MMACs,16-bit 400 MMACs, 32-bit	132 kB L1 SRAM/cache L2 SRAM options of 128 kB 256 kB 512 kB 1 MB 512 kB L2ROM	N/A	ePPI, Sport (2), quad/dual SPI (3), I²C, UART (2), CAN 2.0 B (2), SD/SDIO/MMC (4-bit) USB 2.0 HS OTG	OTP, security accelerator, data integrity (with L1 parity and L2 ECC), WDT, RTC	QFN 88-lead, 12 mm × 12 mm
ADSP-BF701 ADSP-BF703 ADSP-BF705 ADSP-BF707			16-bit LPDDR DDR2	Above options plus SDIO/MMC/eMMC (8-bit) 4-channel, 12-bit ADC		BGA 184-ball 12 mm × 12 mm 0.8 mm

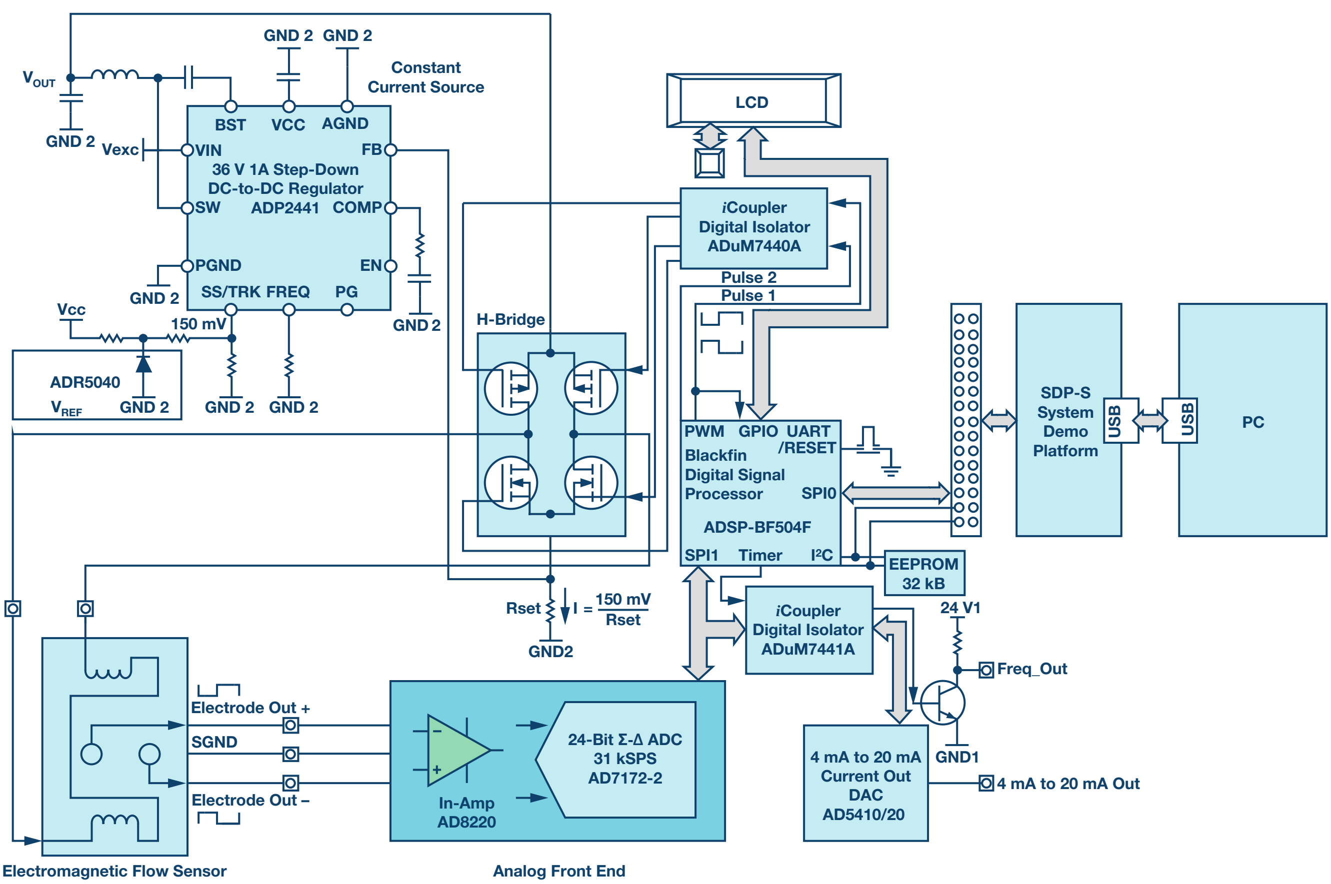

Figure 19. ADI complete solution.

Have You Measured Data from Your Design?

Evaluation Results

The reference design was tested while attached to 25 mm diameter electromagnetic flow sensors on a flow calibration rig with water at room temperature. With the excitation frequency set to 6.25 Hz, the basic error of ±0.2% of reading was achieved in the range of 0.5 meters/sec to 2 meters/sec. The test result data is shown in Table 9.

Table 9. Calibration Results of the Digital Oversampling Demo Board with DN25 Sensor

Flow Rate (mps)	Error of Reading (%)	Repeatability (%)
2.05	–0.14%	0.00%
1.01	0.03%	0.03%
0.49	0.07%	0.04%
0.21	0.42%	0.08%
0.10	1.15%	0.01%
0.05	2.74%	0.06%

Summary and Conclusion

Worldwide, but especially in Europe, more and more environmental regulations are coming on stream to monitor and control waste from both residential and commercial industries. Electromagnetic flow technology is the technology of choice for this application. The traditional architecture tended to be very much an analog approach. This has some disadvantages, such as the cost, area, power, response time, and limited system information. The trend in the industry is toward an oversampled approach. This puts significant challenges on the requirements for the ADC, as the update rates will increase by an order of 10×, but the benefit of averaging cannot be used, which pushes the ADC boundaries in terms of noise requirements at high update rates. There are also power challenges to be solved. The wide range of both liquid types and pipe diameter types create the need for a dynamic power control capability, effectively having a one design that fits all sensor type need with minimum power dissipation. The Blackfin DSP offers the right mix of low power and processing requirements for the flow meter application. It performs complex FIR filter algorithms to calculate flow rates while delivering a class-leading 800 MMACS of processing power at less than 100 mW. The complete design offers a much simplified approach to previous techniques with many advantages of cost, power, and area savings. For more information on ADI's reference design, please contact cic@analog.com.

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