Signal Conditioning Circuits for Sensors

*Frame ASICs**
or
Modular Signal Conditioning

Sensor signals are, by their nature, not perfect and must be corrected with suitable techniques in such a way that target error levels are achieved. One method is to calibrate and compensate the sensor signal with digital components. On the market, there are a few existing integrated solutions which allow such an electronic correction. But often these ICs are not flexible enough or simply not practical to use in sensor applications. This article shows how electronic correction of a sensor system is possible by a clear separation of analog and digital components thereby achieving the target accuracy at a very low cost (labour and material) and eliminating the weaknesses of the monolithic solutions.

*The term ***Frame ASIC*** describes a new class of integrated analog signal conditioning circuits for sensor technology. ***Frame ASIC*** is the name given to an IC whose input, output and analog peripheral functions surround the digital correction facilities of a sensor system and its integrated processor like a frame (see Figure 1).

The idea of ***Frame ASICs*** has evolved from the concept of ***Modular Signal Conditioning***, enabling new applications to be devised simply and flexibly on a sensible budget.

Approaches to Signal Conditioning

To date there have been various approaches to the correction of sensors whose transfer function deviates from the ideal characteristic curve required. These include procedures such as trimming resistors in a correction network (e.g. laser compensation), current compensation (e.g. for pressure sensors with constant current excitation) or compensation processes which involve the use of active components such as transistors or diodes. In the past few years a new way of correction has been suggested which is based on the advances in semiconductor technology and which has already been introduced by a number of companies in the form of 2-chip solutions or monolithic ICs. This approach involves electronic or digital correction which can calibrate, compensate for and linearise a imperfect sensor signal.

Definitions

Calibration:	correction of absolute values, such as offset and span.
Compensation:	correction of induced disturbance variables, such as temperature coefficients and offset drift.
Linearisation:	correction of the measuring system transfer characteristic which is not dependent on the disturbance variables.

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Frame ASICs or *Modular Signal Conditioning*

All of the monolithic IC solutions centring on electronic correction introduced thus far have their specific problems, meaning that a widespread breakthrough for circuits of this kind has not yet been achieved. Where one company may have difficulties with the surface area of the chip (price/device), another's difficulties lie in unsuitable programming for production. Others manufacture chips which require too many external components and others still make promises but fail to meet them beyond the data sheet.

Analog Microelectronics GmbH has devised a simple and cost-effective approach to the problem which is both tried-and-tested, functional, flexible, and cost effective: *Modular Signal Conditioning with Frame ASICs*.

The Concept of Modular Signal Conditioning

If we assume that the analog front end in signal processing (= the sensing element output) almost always has to fulfil the same conditions and that the back end usually has to provide normed output values, then we reach the conclusion that the analog front and back end circuits can be implemented using structures which recur time and again. This means that circuit components such as these can be reduced down to a small number of variations (a prerequisite for IC production), making integration an inexpensive operation.

Requirements regarding accuracy, temperature range and compensation range and in particular the necessary adaptation to individual sensing elements are, however, as manifold as the applications they govern and the sensing elements used. This calls for great flexibility with regard to the relevant digital correction functions and correction elements, a feature which makes IC integration economically and in praxis unviable.

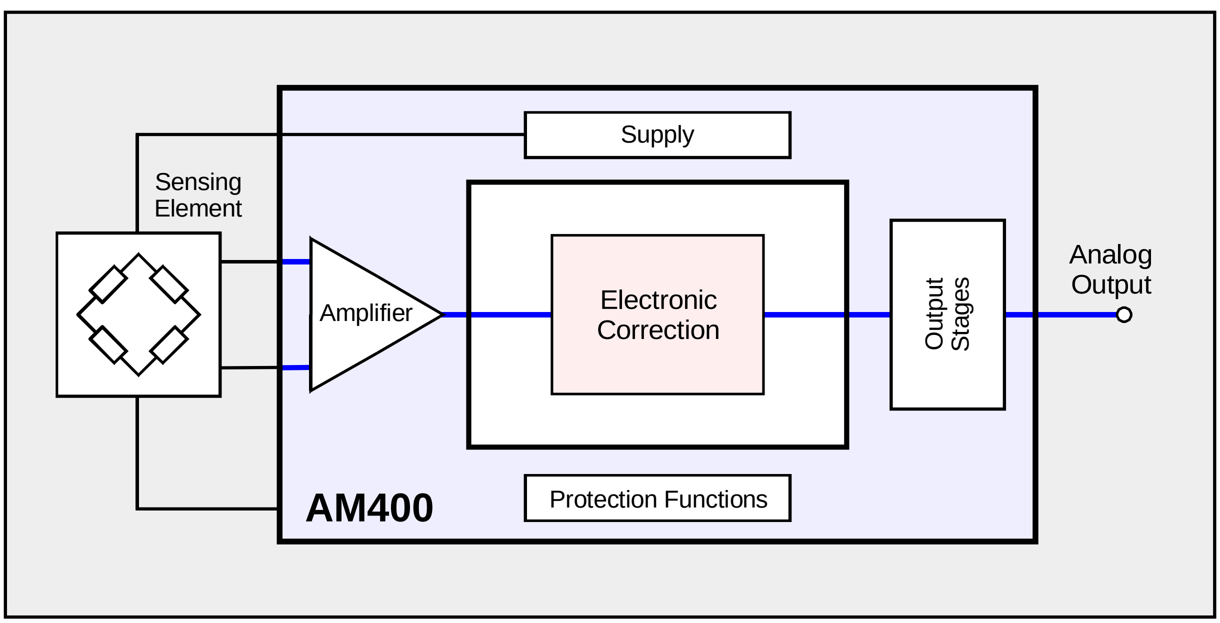

Figure 1: the ***Frame ASIC*** concept

Bearing the various requirements for correction in mind, if we then take a close look at the range of processors and controllers currently available and consider that this market is rapidly moving towards devices which are smaller, cheaper and have more features, then it becomes obvious that the sensor signal conditioning solution is ***Modular Signal Conditioning***.

Solution:

If we take a suitable analog input circuit (instrumentation amplifier) and a standardised output circuit (e.g. 0...10V), add a few peripheral functions, such as temperature detection, voltage reference, protective circuits, current source for the sensing element, and want to accommodate them on an inexpensive integrated circuit, then the device we need is a *Frame ASIC*.

We add a suitable standard processor or controller for correction purposes and will have a signal conditioning system which functions on the principle of *Modular Signal Conditioning*. At last we have a favourable solution, no more technological limitations and a high performance sensor system.

Basic Conditions for Digital Correction

As a general rule, if digital correction is to prove a sensible option and be used to optimum effect, two basic conditions must be observed:

1. The first basic condition to be fulfilled is that the signal can be indirectly or directly modified using a controller or a microprocessor. There are essentially two ways of doing this using the ***Frame ASICs*** manufactured by **Analog Microelectronics GmbH**:

   a) Indirect Modification

   This solution requires external access to the integrated circuit components (e.g. the amplifier) which can alter the offset or span (programming of functions). Here, the analog signal path is not cut and the signal remains unimpaired by either A/D or D/A conversion. The combination of ***Frame ASIC*** and **microprocessor** make up a signal conditioning system which performs the tasks of an "analog sensor signal processor" (see Figure 2). As the path is uncut, the analog signal is modified indirectly and the resolution of the signal nearly unlimited (only by noise).

   b) Direct Modification

   In this approach a controller (with A/D and D/A converters) is connected between the analog front and back end. This form of signal correction is the more extensive as it gives the user greater degrees of freedom and permits him or her to influence the overall signal directly. The quantisation error, resolution and degree of intervention can be largely determined by the digital elements. The combination of ***Frame ASIC*** and **microprocessor** with its A/D and D/A converters make up a signal conditioning system we could refer to as a "digital sensor signal processor" (see Figure 3).

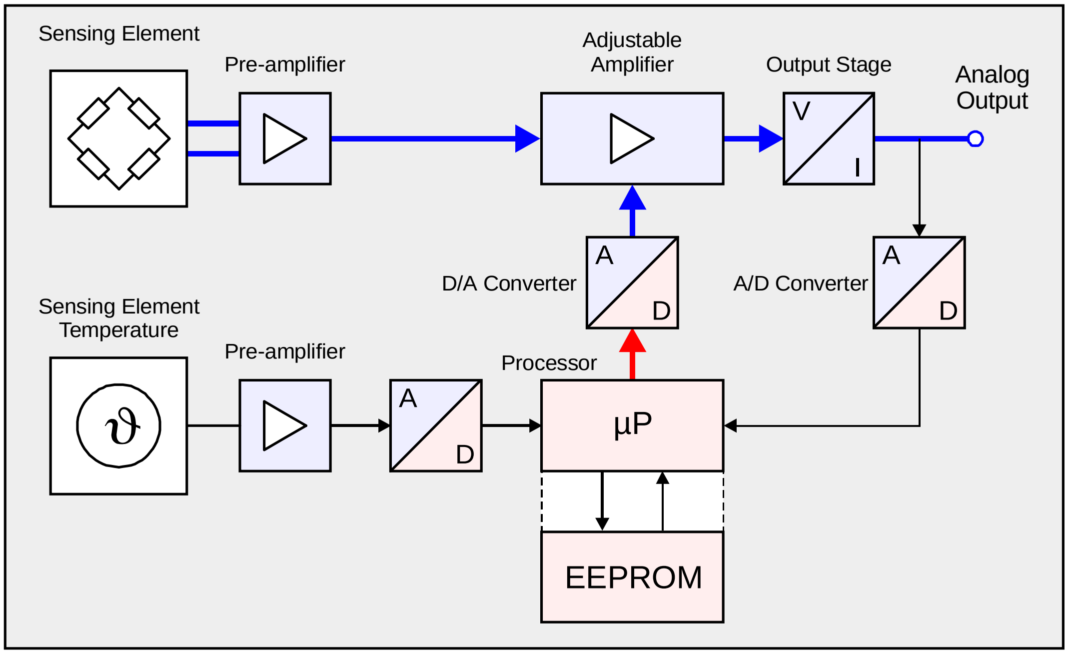

Figure 2: schematic circuit diagram of an analog sensor signal processor

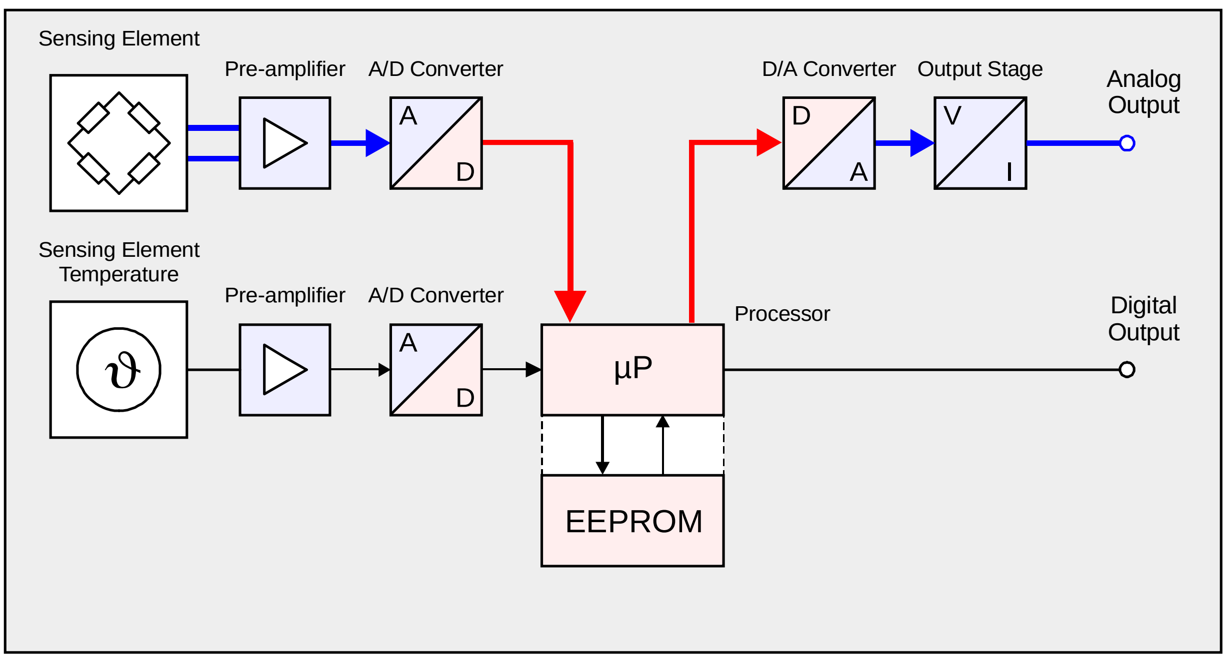

Figure 3: schematic circuit diagram of a digital sensor signal processor

2. The second basic condition governing efficient correction requires that the sensor components (sensor element and signal conditioning electronics) are not compensated for individually but that the sensor circuit as a complete system is corrected to the target output values in its assembled state. Traditional compensation methods entail adding together the errors of the individual sensor components, whereas overall compensation of the system in its entirety involves correcting the resultant error. This is undoubtedly the more exact method, as the total error is not corrected until the end of the production line. Compensating for the finished systems also ties in with the demands of production who are keen to eradicate the influences exerted by assembling and packaging technology and to compensate for sensors once they have been compiled.

Processors and Controllers

If the only corrections necessary are those to calibration and temperature compensation and if an analog output signal is required a simple 8-bit risc processor can be connected to the ***Frame ASICs*** for electronic (digital) signal correction in accordance with ***Modular Signal Conditioning***. In this instance the combined ***Frame ASICs*** and processor function as an analog sensor signal processor (see Figure 5).

Should linearisation, a high degree of accuracy (e.g. < 0.5% in a wide temperature range), or other functions be required, then normally a more complex microcontroller is used which enables suitable application-specific algorithms to be implemented. This system of detection functions as a digital sensor signal processor (see Figure 6).

The use of ***Frame ASICs*** and standard controllers and processors enables inexpensive and problem-specific solutions to be created in the form of stand-alone products. Here, specifically, this is a digitally compensated sensor with a standard analog output and/or a digital output and the necessary protective circuitry. With regard to the aspects outlined here, the principle of ***Modular Signal Conditioning*** is ideally applied when the parent system the sensor is to be integrated into has a processor in operation. If this processor is able to correct the transfer characteristic of the sensor, which is usually the case, then the need for additional components – and thus the cost of the project – is considerably reduced.

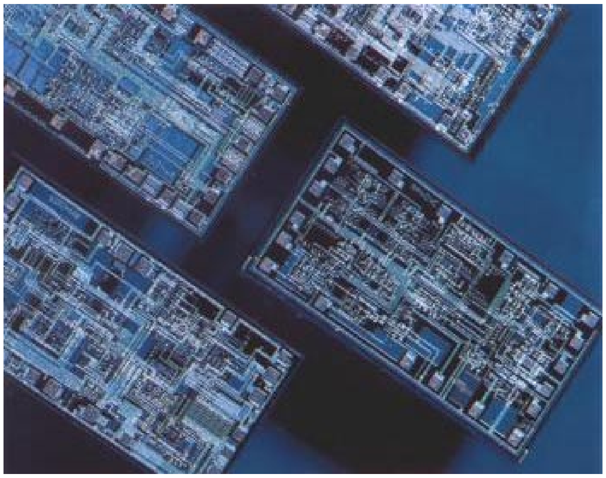

Figure 4: various ***Frame ASICs***

Existing *Frame ASICs*

Based on the concept of ***Modular Signal Conditioning*** the range of ***Frame ASICs*** currently available from **Analog Microelectronics GmbH** includes the following ICs:

AM400 ⇒ for differential input signals and an industrial voltage/current output

AM401/11 ⇒ for differential input signals and an industrial voltage output

AM402/42 ⇒ for differential input signals and an industrial current output

CAN404 ⇒ for capacitive input signals and a Namur output

CAV414 ⇒ for capacitive input signals and an industrial voltage output

Tried-and-Tested Examples

Taking AM400 as an example, the concept of ***Modular Signal Conditioning*** with ***Frame ASICs*** shall be demonstrated here.

A tiny processor which indirectly influences the analog path is connected to AM400 to create an analog sensor signal processor (see Figure 5). In this combination, the offset and the *TCO* and the span and *TCS* of the entire sensor system (sensing element + ASIC) are corrected by influencing the current or voltage source and the adjustable input amplifier of the ***Frame ASIC***. One method of correction would be to calculate correction values from a look-up table stored in the controller. Other methods are also possible, depending on the processor performance.

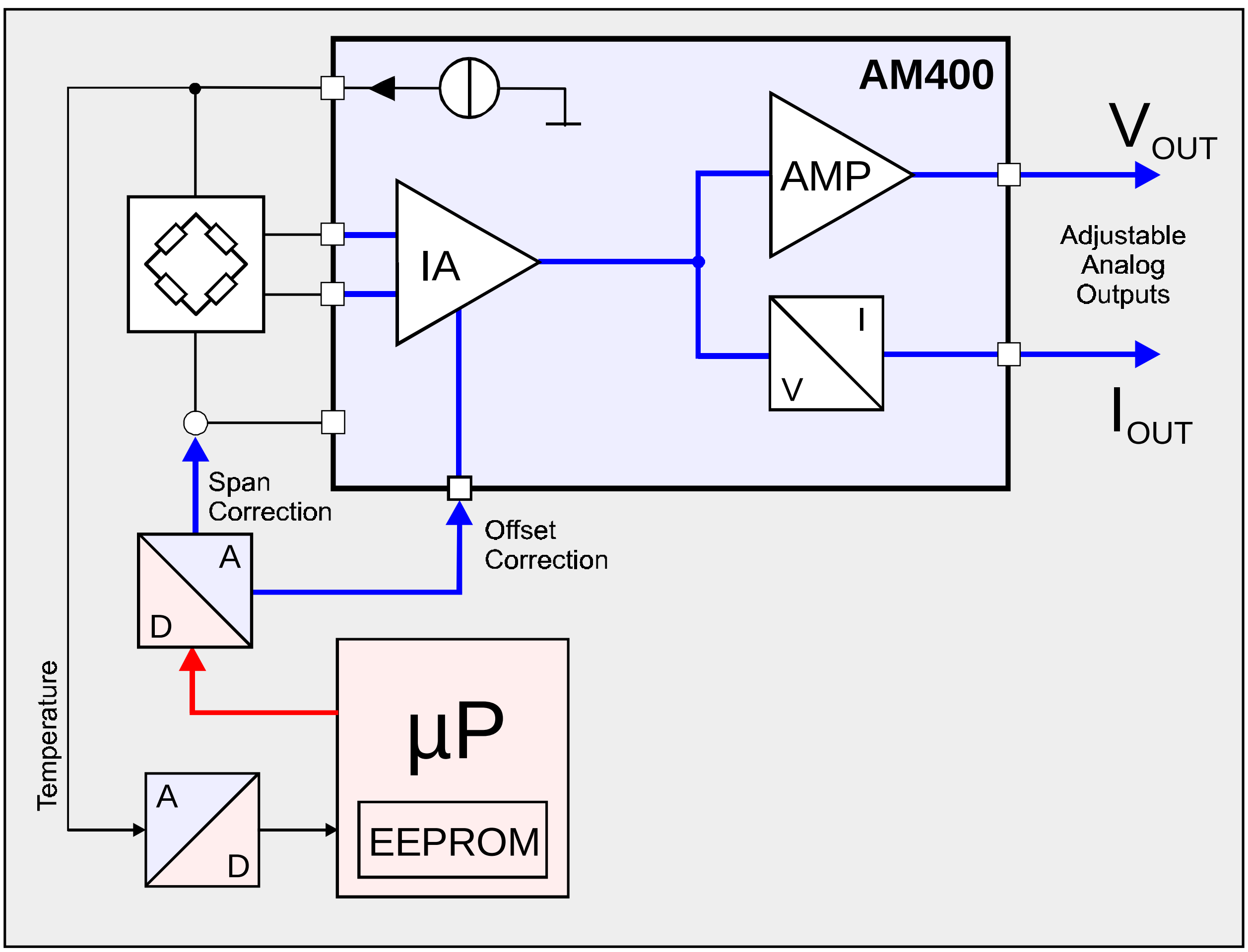

Figure 5: AM400 + controller = analog sensor signal processor

Frame ASICs or *Modular Signal Conditioning*

In order to assemble a digital sensor signal processor, the AM400 analog signal path is cut behind the amplifier unit (in front of the analog output stage). Here there is an analog output (max. value = reference voltage, voltage-limited to protect the converter input following it) which can be used to activate a microcontroller via an ADC. Depending on the profile of the application, in the microcontroller the signal is processed digitally, compensated for and, if necessary, linearised before being converted back into the required industrial output signals in the analog AM400 (see Figure 6) using a DAC for A/D conversion. The sensing element power supply, input and output protection circuits and output area settings for voltage and current outputs are included in the AM400 ***Frame ASIC*** and reduce the number of discrete components needed.

With the latter combination the user is free to use a standard controller to adapt the digital complexity to suit the required signal correction level and additional functions and/or to use existing controllers or processors in the parent system.

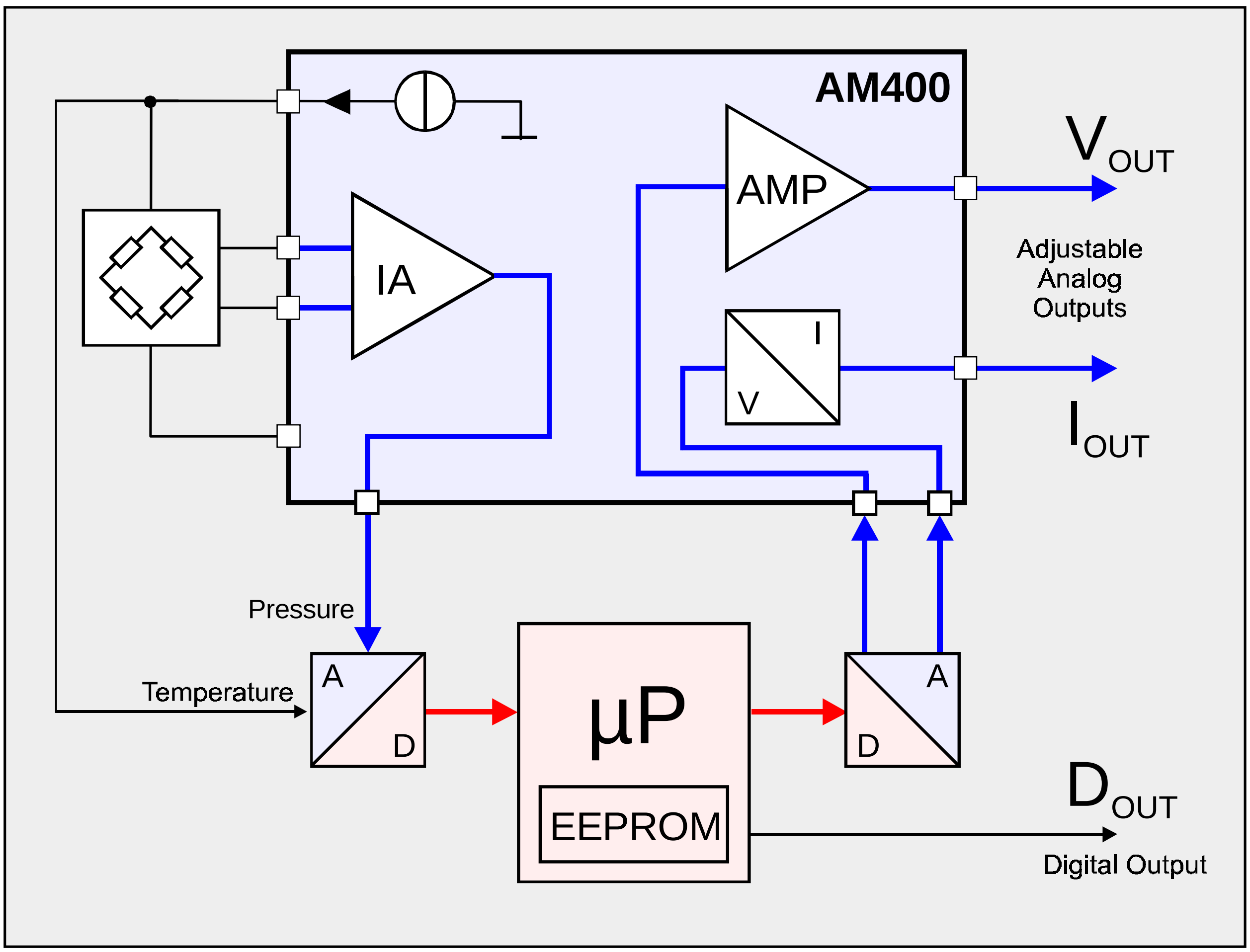

Figure 6: AM400 + microprocessor = digital sensor signal processor for applications requiring high degrees of accuracy and with a digital and analog signal output.

Frame ASICs or *Modular Signal Conditioning*

Analog Microelectronics GmbH is continuing to focus on the concept of ***Frame ASICs*** in its series of ASSPs (application-specific standard products). The new AM400 integrated circuit is one such example. Capable of being modified for specific applications, ***Frame ASICs*** can be tailored to suit a range of customer requirements.

The entire ***Modular Signal Conditioning*** package from **Analog Microelectronics GmbH** can also be offered as a customised design if required.

Detailed data sheets giving dimensional specifications and application notes are available from the **Analog Microelectronics GmbH** website on the Internet:

www.analogmicro.de

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