Temperature sensor based on integrated circuits AM401

The company LKM electronic GmbH, Germany [1] aimed to build a sensor for recording room temperature with an analog output signal of 0...10V. For reasons of both technicality and economy a semiconductor element was used as a measuring cell and an integrated circuit as a signal processing unit with a minimum of external elements The following article describes how a temperature sensor such as the one required can be assembled.

The temperature sensing element

An LM60 semiconductor sensor from National Semiconductor was selected as a temperature measurement element. The LM60 is a calibrated, integrated temperature sensor which can record temperatures within a range of -40 to 125°C and works at a supply voltage of between 2.7 and 10V. The analog voltage output is linearly proportional to the recorded temperature and has a slope of +6.25mV/°C plus an offset of 425mV so that negative temperatures can also be measured. The output thus covers a range of 174mV to 1.205V at -40 to 125°C.

The signal conditioning circuit

In principle there were two possibilities for the signal conditioning unit: a discrete setup or an integrated circuit.

Taking the sensor's industrial use into account, in order to be able to amplify the transducer and generate the 0...10V output signal a linear, adjustable amplifier, linear regulator, reference voltage source and circuitry protecting against short-circuits and reverse polarity were required. A discrete solution satisfying these requirements would, however, have the following disadvantages:

- **Domestic power consumption:** Due to the large number of components listed above, at a supply voltage of 24V the required power for such a setup would amount to ca. 5mA. Used as a room temperature probe in an almost completely closed package, at 120mW the setup's rise in temperature can no longer be ignored. Enlarging the package openings or placing the sensor outside the package is not constructively feasible.
- **Design time:** The lack of application support for standard devices would result in longer design times. The need for protective units against short-circuits and reverse polarity must also be taken into account, requiring additional components. Adjusting operational amplifiers to the supply voltage (rail-to-rail) is always not possible.
- **Cost and acquisition:** The larger the number of components, the greater the logistical effort. Mounting a printed board with so many components is more expensive and more susceptible to error than an integrated solution.

The above are reason enough to favor the use of a suitable integrated circuit, embodied in the voltage transmitter IC AM401 from Analog Microelectronics GmbH, Germany [2].

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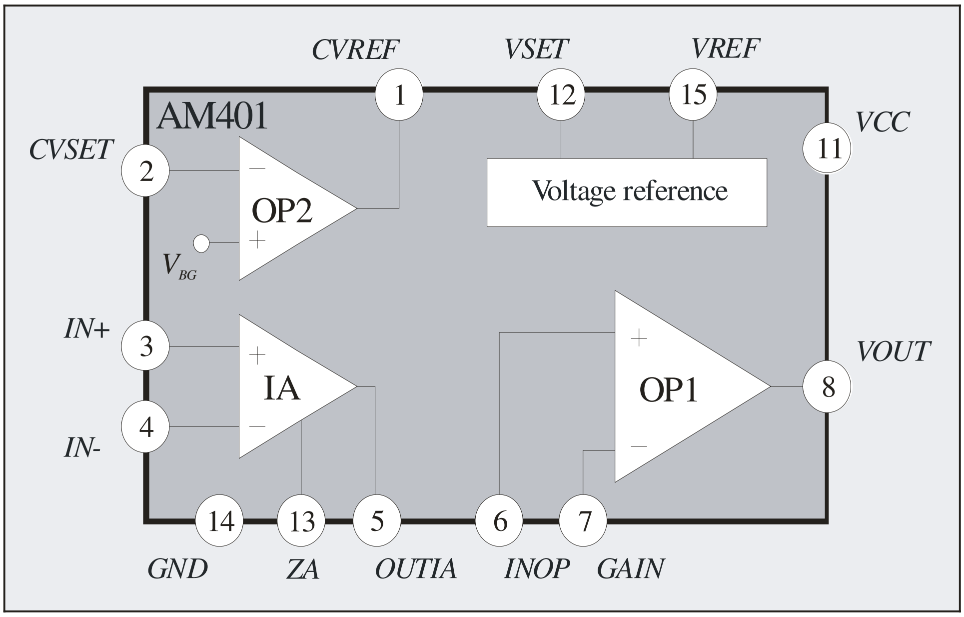

Figure 1: Block diagram of AM401

The signal conditioning IC AM401

In AM401 Analog Microelectronics GmbH provides a monolithically integrated amplifier IC with a range of additional and protective functions which is best tailored to suit the necessary requirements.

A suitable circuit assembled using AM401 had the following advantages:

- **Domestic power consumption:** At a supply voltage of 24V the power required by the entire circuit was just ca. 1mA. Unlike the previous system this setup's increase in heat when used as a room temperature probe was so low as to be practically negligible.
- **Design time:** The availability of a detailed data sheet containing example calculations enabled the design period to be kept brief. The IC is protected against reverse polarity and other switching errors. The output signal can be adjusted to almost 0V without any problem. Due to the low number of components the printed board was developed in a short space of time.
- **Cost and acquisition:** As far fewer components were required storage and acquisition were reduced. Assembly costs were also considerably lowered. Finally, the lower number of discrete components led to an improvement in the overall reliability.

Details of the integrated AM401

AM401 is a monolithically integrated voltage transmitter which has been developed for both the processing of differential bridge voltages and the conversion of asymmetrical voltage signals. The IC has been specifically designed to provide systems designers with a universal industrial device for analog signal processing.

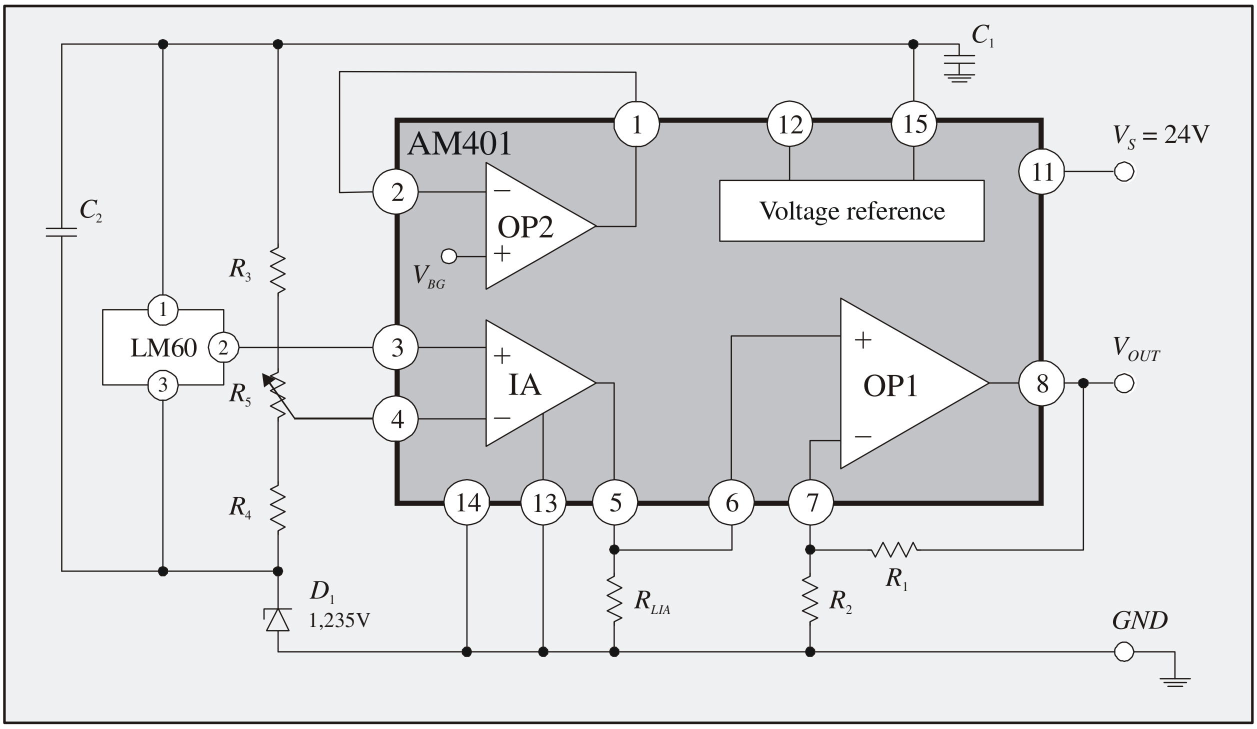

Figure 2: Temperature sensor circuitry

By varying the few external components the output voltage can be adjusted over a wide range. All function blocks can be individually accessed, enabling each one to be used a separate functional unit. As shown in the application examples these can also be connected up using external components to form function modules, making this IC universally applicable and able to replace many individual components. Typical values for the external components are given in the AM401 data sheet.

The circuit basically consists of the following function blocks (see *Fig.1*):

1. The *instrumentation amplifier* (IA) with an internal gain of $G_{IA} = 5$ acts as an input stage for differential voltage signals. Its configuration is such that a high common-mode rejection rate (CMRR) is achieved. The amplifier reference potential is set externally using AM401's *ZA* pin. The output voltage V_{OUTIA} at pin *OUTIA* is calculated for $V_{ZA} > 0$ as:

$$V_{OUTIA} = G_{IA}\, V_{IN} + V_{ZA} \text{ with } V_{OUTIA} > 0 \qquad (1),$$

   where V_{IN} is the differential voltage between the inputs pin *IN+* and pin *IN-* of the IA and V_{ZA} is the voltage at pin *ZA*.

2. The ensuing *operational amplifier stage* (OP1) enables the IA's output signal to be amplified further. OP1's gain G_{GAIN} can be set using external resistors R_1 and R_2. The output voltage V_{OUT} at pin *VOUT* is calculated as:

$$V_{OUT} = V_{INOP} \cdot G_{GAIN} \text{ with } G_{GAIN} = \left(\frac{R_1}{R_2} + 1 \right) \qquad (2),$$

where V_{INOP} is the voltage at OP1's input pin *INOP*. Alternatively, this input pin can also be used as an input for signals referenced to ground. The output stage is protected against reverse polarity and has an output current limit.

3. AM401's *reference voltage source* enables the voltage supply of external components, such as sensors, microprocessors and the like. Reference voltage V_{REF} can be set using pin *VSET*. If *VSET* is not connected up, $V_{REF} = 5V$; if *VSET* is referenced to ground, $V_{REF} = 10V$. Interim values can also be set if two external resistors are used (placed between pins *VREF* and *VSET* and between pin *VSET* and *GND*).

4. The second *operational amplifier* (OP2) can be used as a current or voltage source for the supply of external components. OP2's positive input is connected up internally to voltage V_{BG}, allowing the output current or voltage to be set by one or two external resistors across a wide range.

The supply voltage can be between 6 and 35V, depending on the output voltage.

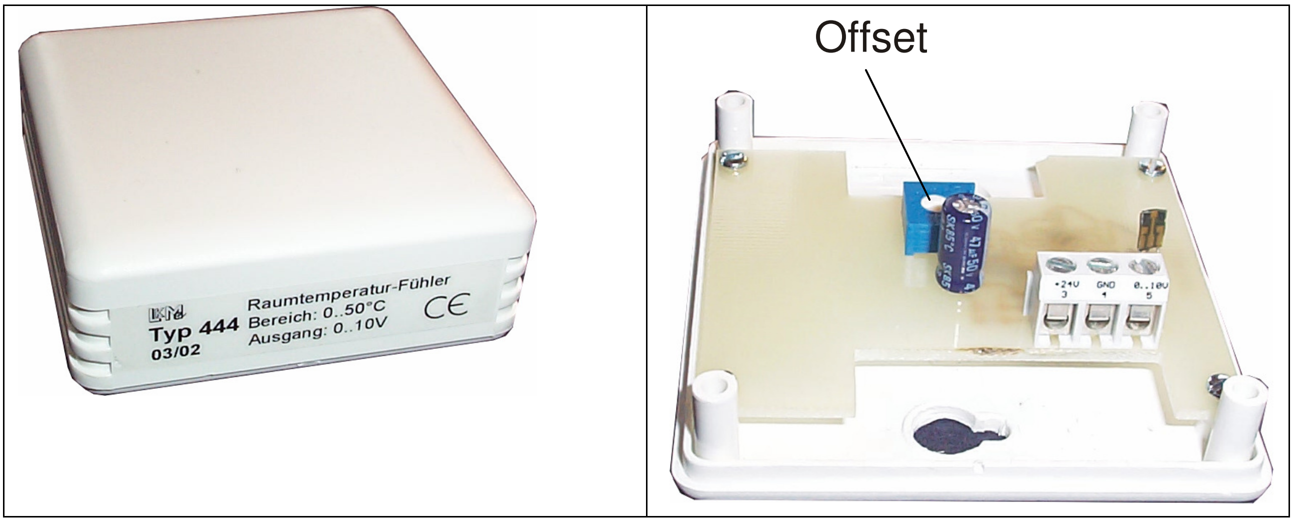

Figure 3: Assembled room temperature sensor system

The sensor is connected up to the positive input of AM401's instrumentation amplifier (see the application described in *Figure 2*). A reference voltage, whose value is determined by the minimum operating temperature, is linked up to the negative input of the instrumentation amplifier. As AM401's common-mode input range (*CMIR*) does not extend as far as ground, the voltage of a reference diode is added to the input signal.

The output amplifier gain is set using resistors R_1 and R_2 according to the maximum upper operating temperature. AM401's internal voltage reference acts as the temperature sensor supply. Adjustments can be made using the available R_5 regulator; depending on the dimensioning of resistors R_1 and R_2 a different voltage signal can also be obtained, such as 0...1V, for example.

The entire circuit has been assembled in a package suitable for wall mounting (see *Fig. 3*)

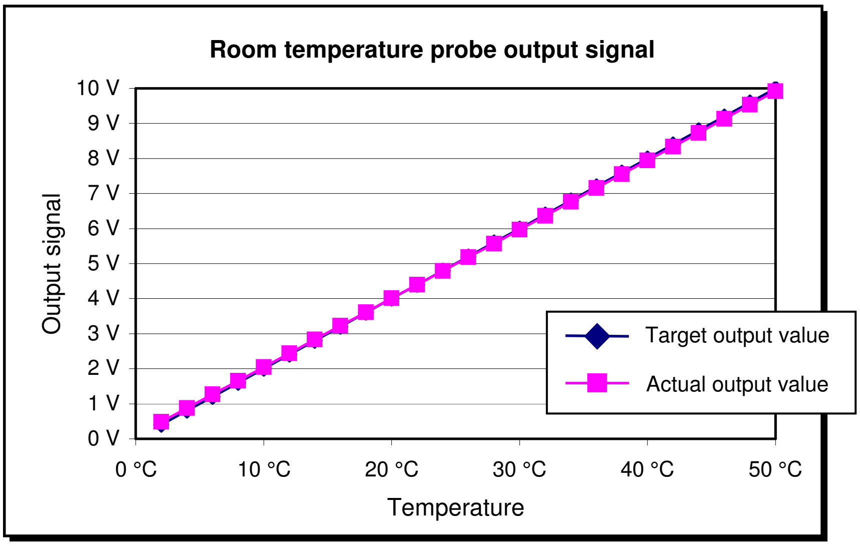

Figure 4: Output characteristics for the room temperature probe

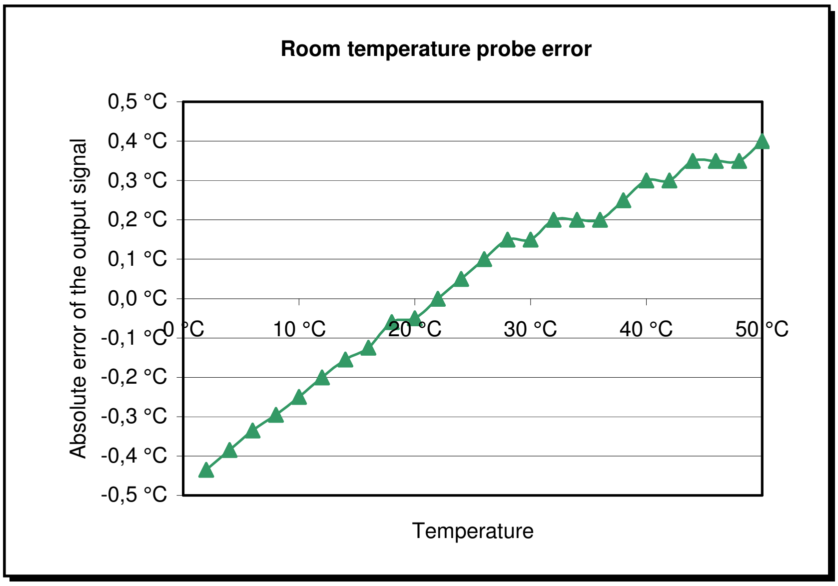

Figure 5: Degree of error of the room temperature measurement

Measurements

Measurements were made using the assembled room temperature sensor. Figure 4 gives the sensor's output characteristics. Within a range of 2.5 to 50°C a maximum error of measurement of 0.8°C was obtained which corresponds to the required level of accuracy. The absolute errors for the individual temperatures are given in *Figure 5*.

Conclusion

In AM401 Analog Microelectronics has produced an IC which is suitable for a variety of applications. In collaboration with the company LKM electronic GmbH a room temperature sensor was developed which has already gone into production and proved itself in series. In the example given here this article has attempted to demonstrate that using just very few semiconductor components circuits can now be assembled which until recently would have required a considerable number of discrete elements.

Remarks

The content of this article is available also for the AM411.

Further reading

You will find detailed information on the products dealt with in this article under the following links:

[1] LKM electronic GmbH website:

http://www.lkmelectronic.de

[2] Analog Microelectronics GmbH website:

http://www.analogmicro.de