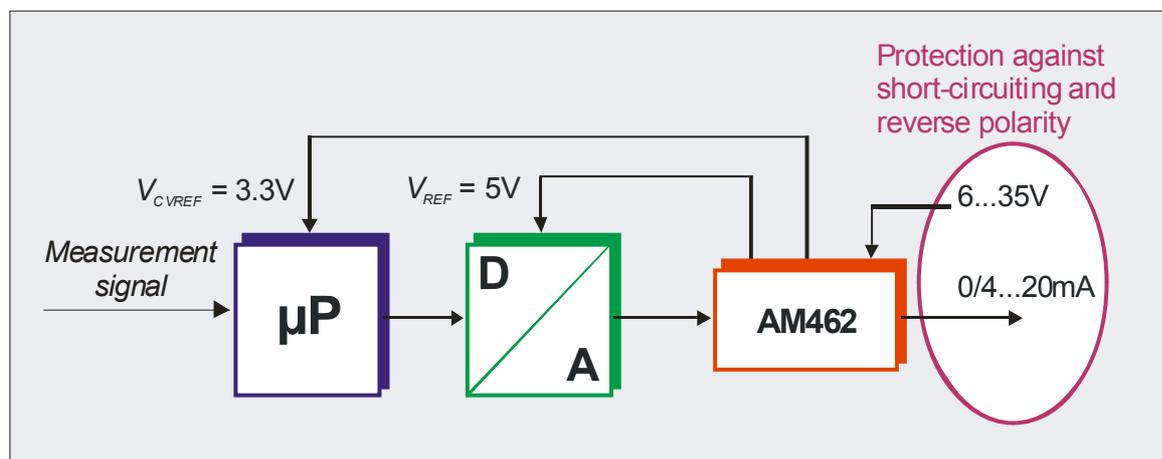


## 4...20mA Interface-IC AM462 for industrial $\mu$ -processor applications

Because of the great number of industrial buses now available the majority of industrial measurement technology applications still calls for the standard analog current network. The reason for this lies in the fact that with an analog current output of 0/4...20mA of a signal conditioning system a simple and relatively cheap interfaces can be created which is immune to interference and which allows a long distance communication. .

Assuming that the above scenario is applicable to typical industrial setups (*Figure 1*), where a measurement signal is processed in a microprocessor (e.g. signal correction), the digitized signal must then be adapted to suit industrial analog requirements.

The following article presents a new industrial current interface IC AM462 which has been specifically designed as an analog microprocessor interface for the industrial network which can also be operated as a stand-alone IC for industrial signal amplification (V/I Converter-IC).



*Figure 1:* Typical industrial application of AM462

### Simple analog circuits

For industrial applications which require current outputs of 0/4...20mA, roughly speaking a multiple operational amplifier (OP) can be used as an output circuit and a discrete circuit assembled. A solution such as this, however, is only very basic. Depending on the application, with regard to the overall system a stable output current (which is as independent of the temperature and supply voltage as possible) and also other functions must be realized which bring a direct influence to bear on the output stage. These functions include protective circuitry, voltage adjustment facilities, reference sources et cetera, all of which go far beyond the limits of a simple OP circuit and – in order to meet the given requirements – call for a not inconsiderable knowledge of analog circuit technology.

Although a number of integrated components permitting assembly with the functions mentioned above are now available on the market, there are several major disadvantages of working with a more or less discrete solution:

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- **Miniaturization:** The more complex the application, the greater the space required – which may have to be compensated for using expensive miniaturized components.
- **Economic pressures:** The discrete components currently available often do not meet the requirements of the application on hand (e.g. regarding temperature behavior), resulting in more demanding circuitry, all of which adds up to a more costly solution.
- **Acquisition difficulties:** Problems of logistics arise when the solution design requires specific component models: "The device you require is unfortunately not available for the next six months"!
- **Design time:** The lack of application support which often goes hand in hand with standard devices results in more hours of engineering and thus higher costs. System protection against short-circuiting may have to be taken into consideration, for example, or perhaps the temperature effects of the reference compensated for.

Integrated ASSPs (application-specific standard products) are an alternative to the discrete solution, their high degree of specialization – combined with the advantage of being in a miniaturized form – greatly simplifying a number of applications and thus making products generally increasingly less expensive.

### AM462 – Analog-IC with an industrial current loop output

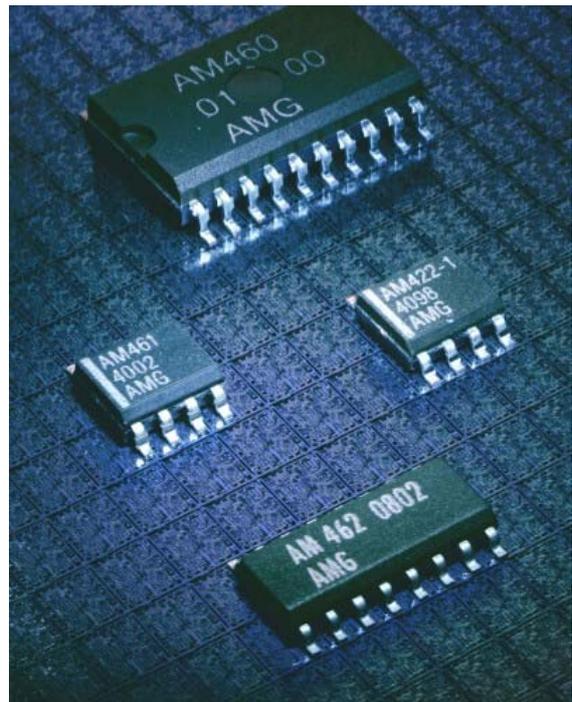
In the interface IC AM462 Analog Microelectronics GmbH [1] can now offer a monolithically integrated circuit which is part of a new series of industrial amplifier ICs. This special chip has been developed with the aim of providing engineers with a universal V/I converter device with an adjustable voltage input and current output which can be used as an analog output stage for processor applications following D/A conversion, for example.

AM462 (see *Figure 3*) is a multistage amplifier IC with a range of modular additional and protective functions which can be used as required, providing a high degree of functionality. The IC is modular throughout. All function blocks can be individually accessed via the relevant pins and connected up externally or operated separately.

### AM462 with different function blocks:

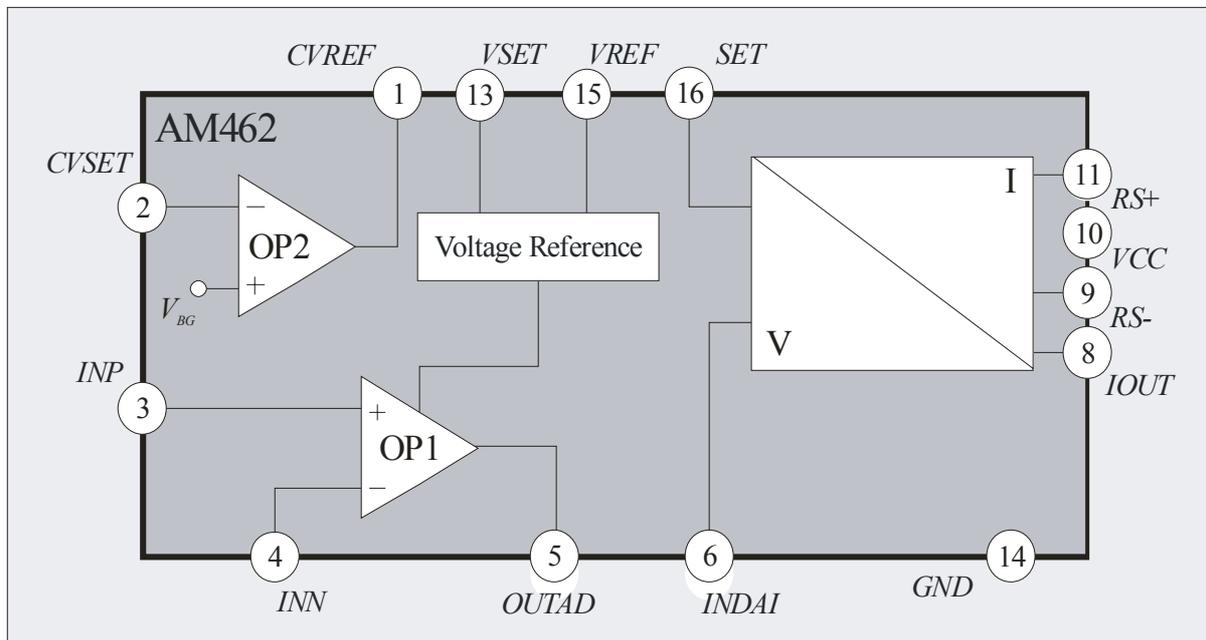
#### 1. An operational amplifier

This amplifier stage (OP1) is suitable for input signals of 0 to VCC-5V. The amplification is set using external resistors. The output of the operational amplifier stage has been designed so that it can be set right down to 0 if the load requires. OP1 is voltage limited, protecting follow-on stages even when overvoltage occurs on the input side of the device.



*Figure 2:* New series of amplifier and protective ICs as industrial output ICs for processor applications

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**Figure 3:** Block diagram of V/I Converter IC AM462

### 2. A V/I converter stage

On the output side of the device the *V/I converter stage* translates the input voltage into a freely selectable output current of between 0 and 20mA. In doing so the converter output stage activates an external transistor (*Figure 4*) which ensures that power is dissipated outside the IC. The output current range for the current offset and final current value can be easily set using two external voltage dividers.

### 3. A bandgap reference

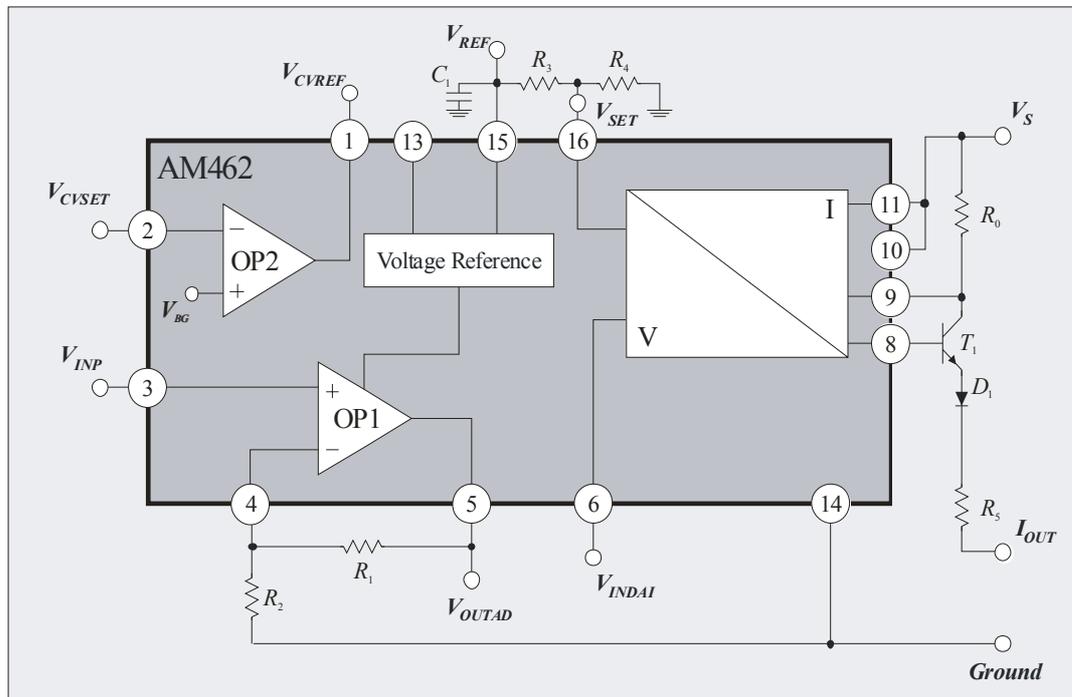
The *reference voltage source* included in AM462 enables external components, such as sensors and microprocessors etc., to be supplied with voltage. Reference voltage  $V_{REF}$  can be set using pin  $VSET$ . If pin  $VSET$  is not connected,  $V_{REF} = 5V$ ; if  $VSET$  is connected to ground,  $V_{REF} = 10V$ . Using two external resistors (inserted between pins  $VREF$  and  $VSET$  and pins  $VSET$  and  $GND$ ) intermediate values can also be set.

### 4. An operational amplifier

A second *operational amplifier* (OP2) can be used as a current or voltage source to power external components. OP2's positive input is connected internally to voltage  $V_{BG}$ , enabling the output current or voltage to be set within a wide range using one or two external resistors. The output of this additional operational amplifier has a drive power of 10mA.

The IC also includes internal circuitry protecting amplifier stage OP1 against overvoltage, integrated protection against reverse polarity with regard to the output stage (V/I converter) across the entire voltage range and an output current limiter which protects the IC against destruction. Using just a minimum of external circuitry an output stage can thus be realized which is fully protected.

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**Figure 4:** AM462 as typical V/I Converter-IC-circuitry

### Using AM462 as an industrial processor output stage

Many of today's applications incorporate inexpensive RISC processors. These are suitable for signal correction (compensation, calibration, linearization, etc.), for example, as driver units with the relevant algorithms and, if need be, also for identification purposes. Should a current (output) signal be required by the overall system for further signal conditioning, after passing through the processor the digital signal information must be converted into an analog signal. If the processor does not include an integrated D/A converter, the digital signal then has to be translated by alternative means, such as via a PWM (pulse-width modulation) signal with a follow-on low-pass filter. The signal is then converted into the required current signal by AM462 (see the schematic diagrams in Figures 4 and 5).

In the suggested application a standard processor in Amtel's AVR series (an ATtiny11) was used. ATtiny11 is a fully-static CMOS RISC processor in an 8-pin SO package with 1kb of rewritable flash ROM, 32 bytes of RAM-type registers and a 1MHz clock frequency. The processor does not require an external clock or quartz as it comes with an internal RC oscillator. Depending on the processor type the supply voltage ranges from a maximum of 2.7V...5.5V at a power consumption of ca. 4mA. For all types the operating temperature range is from -55 to +125°C. The flash memory can either be programmed via the expansion port on the Atmel evaluation board, using special programming units from other suppliers or by domestic assemblies by means of digital signal.

As the selected RISC processor has neither its own A/D or D/A converter nor a frequency output nor PWM outputs realized by hardware, digital-to-analog conversion must be realized by appropriate software using the given processor outputs.

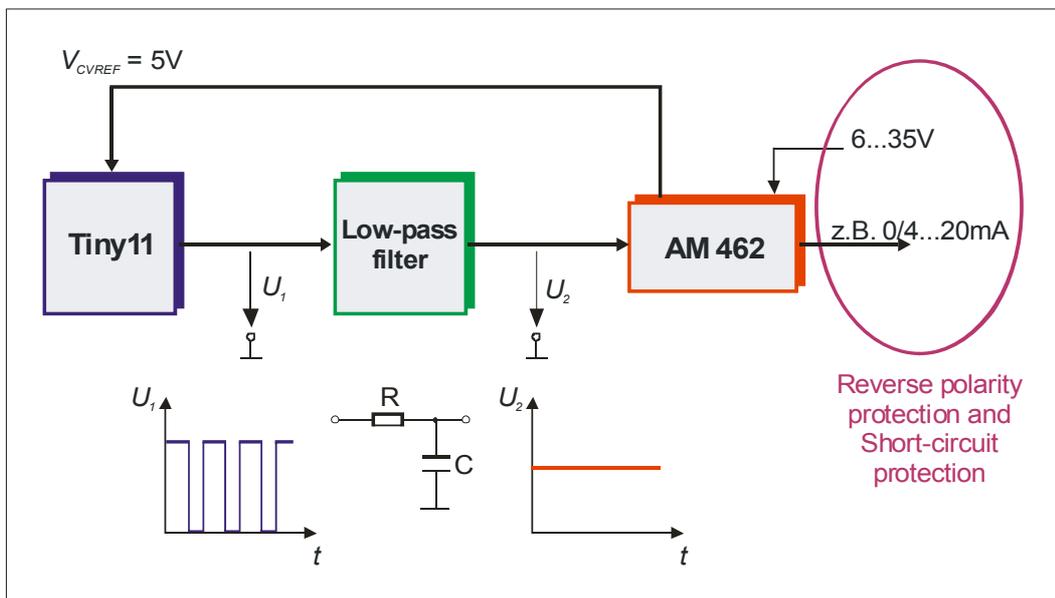
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### PWM output as a substitute DAC

For the purpose of digital-to-analog conversion one of the ATtiny11 I/O pins is programmed as a PWM output. It provides two discrete voltages of 0 and 5V and is switched on and off periodically within a defined time span by software, with the pulse width matching the digital value. The resulting square-wave signal (PWM signal) is filtered in a follow-on low-pass filter, producing an average DC output signal ( $U_2$ ) which is proportional to the duty cycle. The following applies:

$$U_2 = \frac{1}{T} \int_{t_0}^{t_0+t_1} U(t) dt \longrightarrow U_2 = U_1 \frac{tp}{T}$$

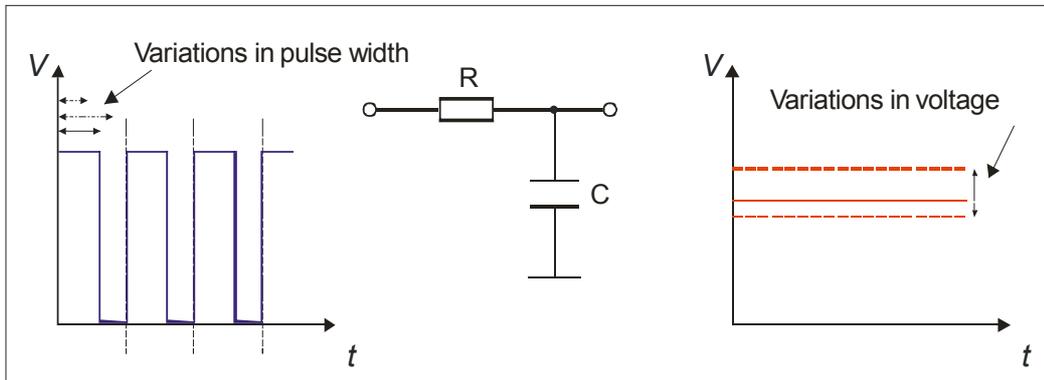
where  $1/T$  is equivalent to the basic frequency of the PWM signal,  $tp$  the pulse width and  $tp/T$  the duty cycle. A mean voltage is thus produced by the low-pass filter which is both proportional to the duty cycle and provides the AM462 with an input voltage (Figures 5 and 6). The rectified PWM signal is thus the voltage  $U_2$  which AM462 then converts into a standard current signal of 0/4 to 20mA, for example. As AM462 is a purely analog IC the achievable resolution of the output signal is equivalent to the quantization of the length of the switch-on/switch-off time.



**Figure 5:** Typical industrial application of AM 462 with a RISC processor

As the processor's own power consumption is well below 10mA this can be supplied by AM462's current source. AM462 could also be used to power an existing signal conditioning circuit (e.g. 3.3 or 5V). The supply of additional components by the output IC has the advantage of thermal matching, thus reducing the temperature error. Furthermore, all components which are powered by AM462 are also guarded by the IC's protective circuitry.

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**Figure 6:** The voltage signal changes with variations in the pulse width

### Conclusion

In AM462 Analog Microelectronics has produced an IC which is suitable for a variety of applications. Its use as an industrial output circuit (20mA current loop) In a processor circuitry has been illustrated in this article. Its many functional modules and protective units enable a lot of different industrial circuits to be realized.

### Remarks

The new AM461 [2] can be used in the same application, differing from AM462 only in that it generates an adjustable output voltage signal.

The article described a 3 wires solution because the current consumption of the RISC processor together with the IC consumption is in the high temperature range at the limit of 4mA. With a processor of lower current consumption or with a lower conversion frequency it should be possible to realize also 2-wires applications.

The content of this article is available also for the AM422 [3], who has fewer functions and is cheaper as the described AM462.

### Further reading

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

- [1] Analog Microelectronics : <http://www.analogmicro.de>
- [2] Data Sheets: Data Sheet AM461
- [3] Data Sheets: Data Sheet AM422