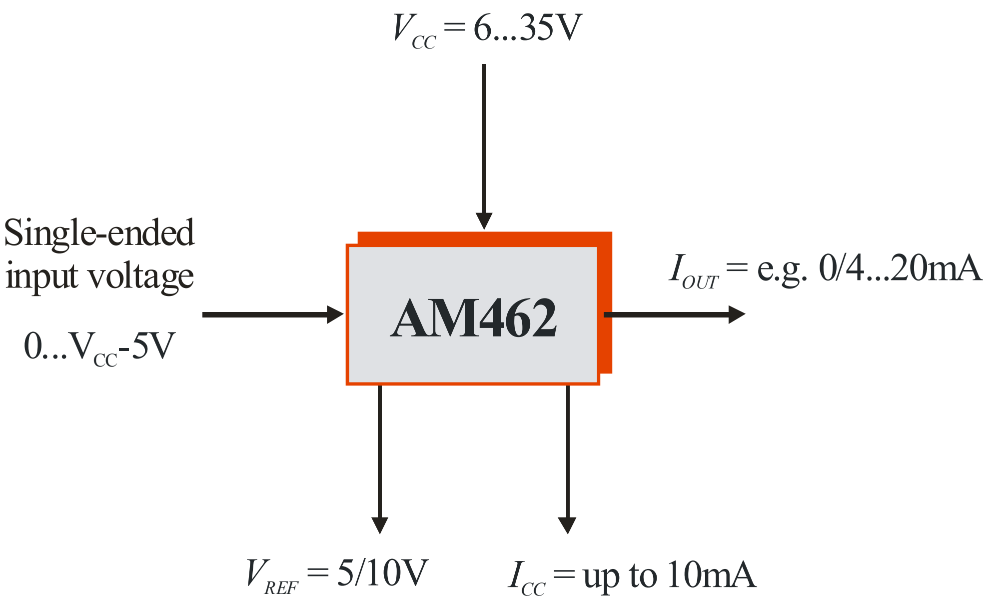
Industrial V/I Converter and Protector IC
AM462

PRINCIPLE FUNCTION

Conversion of input voltage referenced to ground to output current
Integrated protection for IC and external components
Integrated, adjustable current/voltage sources for external components



TYPICAL APPLICATIONS

- Adjustable voltage-to-current (V/I) converter
- Adjustable voltage and current source (supply unit)
- Voltage regulator with additional functions
- Industrial protector and output IC for microprocessors (the Frame ASIC concept [1])
- Peripheral processor IC
- For examples of typical applications see *Example Applications*

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Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de

Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

Industrial V/I Converter and Protector IC AM462

CONTENTS

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de

Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

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FEATURES

- **Supply voltage: 6...35V**
- **Wide working temperature range: –40°C...+85°C**
- **Adjustable integrated reference voltage source: 4.5 to 10V**
- **Additional voltage/current source**
- **Adjustable amplification**
- **Adjustable offset**
- **Industrial current output (e.g. 0/4...20mA)**
- **Protection against reverse polarity**
- **Short-circuit protection**
- **Output current limitation**
- **Low-cost device: replaces a number of discrete elements**
- **2- and 3-wire operation**
- **Individually configurable function modules**
- **RoHS compilant**

GENERAL DESCRIPTION

AM462 is a universal V/I converter and amplifier IC with a number of additional functions. The IC basically consists of an amplifier, whose gain can be set externally, and an output stage which can convert voltage signals referenced to ground to industrial current signals. An additional reference voltage source for the supply of external components is also included in the device. A further operational amplifier can be connected up as a current source, voltage reference or comparator.

One of the main features of the IC is its integrated protective circuitry. The device is protected against reverse polarity and has a built-in output current limit. Converter IC AM462 enables industrial current loop signals (e.g. of 0/4–20mA) to be produced relatively easily.
Using the Frame ASIC concept [1] the IC can be connected up to a processor for signal correction.

BLOCK DIAGRAM

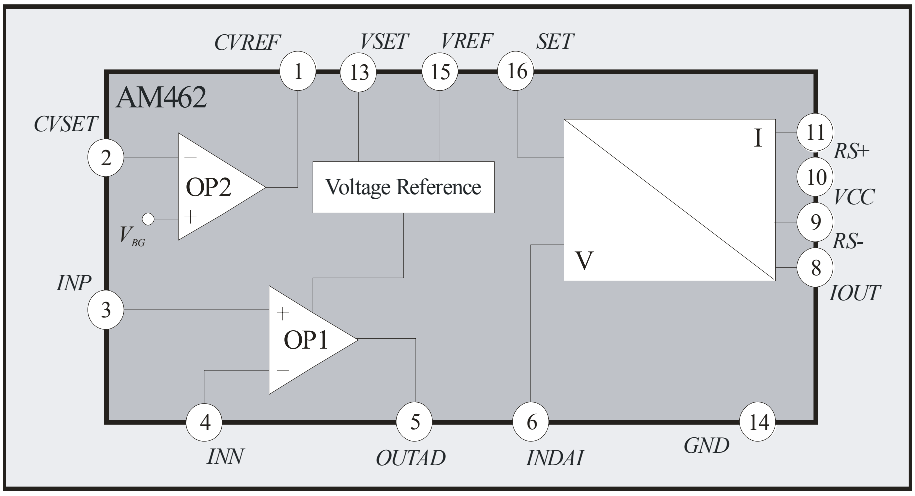

Figure 1: Block diagram of AM462 (individually configurable function modules)

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

ELECTRICAL SPECIFICATIONS

T_{amb} = 25°C, V_{CC} = 24V, V_{REF} = 5V, I_{REF} = 1mA (unless otherwise stated); currents flowing into the IC are negative.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage Range	V_{CC}		6		35	V
Quiescent Current	I_{CC}	T_{amb} = - 40...+85°C, I_{REF} = 0mA			1.5	mA
Temperature Specifications						
Operating	T_{amb}		-40		85	°C
Storage	T_{st}		-55		125	°C
Junction	T_J				150	°C
Thermal Resistance	Θ_{ja}	DIL16 plastic package		70		°C/W
	Θ_{ja}	SO16 narrow plastic package		140		°C/W
Voltage Reference						
Voltage	V_{REF}	*VSET* not connected	4.75	5.00	5.25	V
	V_{REF10}	$VSET = GND$, $V_{CC} \geq$ 11V	9.5	10.0	10.5	V
Trim Range	V_{REFADJ}		4.5		V_{REF10}	V
Current	I_{REF}*		0		10.0	mA
V_{REF} vs. Temperature	dV_{REF}/dT	T_{amb} = - 40...+85°C		±90	±140	ppm/°C
Line Regulation	dV_{REF}/dV	V_{CC} = 6V...35V		30	80	ppm/V
	dV_{REF}/dV	V_{CC} = 6V...35V, $I_{REF} \approx$ 5mA		60	150	ppm/V
Load Regulation	dV_{REF}/dI			0.05	0.10	%/mA
	dV_{REF}/dI	$I_{REF} \approx$ 5mA		0.06	0.15	%/mA
Load Capacitance	C_L		1.9	2.2	5.0	µF
Current/Voltage Source OP2						
Internal Reference	V_{BG}		1.20	1.27	1.35	V
V_{BG} vs. Temperature	dV_{BG}/dT	T_{amb} = – 40...+85°C		±60	±140	ppm/°C
Current Source: $I_{CV} = V_{BG}/R_{SET}$, from Figure 5						
Adjustable Current Range	I_{CV}*		0		10	mA
Output Voltage	V_{CV}	V_{CC} < 19V	V_{BG}		V_{CC} – 4	V
	V_{CV}	$V_{CC} \geq$ 19V	V_{BG}		15	V
Voltage Source: $V_{CV} = V_{BG}$ $(1 + R_7 / R_6)$, from Figure 6						
Adjustable Voltage Range	V_{CV}	V_{CC} < 19V	0.4		V_{CC} – 4	V
	V_{CV}	$V_{CC} \geq$ 19V	0.4		15	V
Output Current	I_{CV}*	Source			10	mA
	I_{CV}	Sink			–100	µA
Load Capacitance	C_L	Source mode	0	1	10	nF
Operational Amplifier Gain Stage (OP1)						
Adjustable Gain	G_{GAIN}		1			
Input Range	*IR*	V_{CC} < 10V	0		V_{CC} – 5	V
	IR	$V_{CC} \geq$ 10V	0		5	V
Power Supply Rejection Ratio	*PSRR*		80	90		dB
Offset Voltage	V_{OS}			±0.5	±2	mV

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Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

Parameter	**Symbol**	**Conditions**	**Min.**	**Typ.**	**Max.**	**Unit**
Operational Amplifier Gain Stage (OP1) (cont.)						
V_{OS} vs. Temperature	dV_{OS}/dT			±3	±7	µV/°C
Input Bias Current	I_B			10	25	nA
I_B vs. Temperature	dI_B/dT			7	20	pA/°C
Output Voltage Limitation	V_{LIM}			V_{REF}		V
Output Voltage Range	V_{OUTAD}	$V_{CC} < 10V$	0		$V_{CC} - 5$	V
	V_{OUTAD}	$V_{CC} \geq 10V$	0		V_{REF}	V
Load Capacitance	C_L				250	pF
V/I Converter						
Internal Gain	G_{VI}		0,12	0.125	0,13	
Trim Range		Adjustable by R_0	0.75	1.00	1.25	
Voltage Range at R_0 FS	$V_{R0}FS$		350		750	mV
Offset Voltage	V_{OS}	$\square_F \geq 100$		±2	±4	mV
V_{OS} vs. Temperature	dV_{OS}/dT	$\square_F \geq 100$		±7	±14	µV/°C
Input Resistance	R_{IN}		120	160		kΩ
R_{IN} vs. Temperature	dR_{IN}/dT		0.2	0.3		kΩ/°C
Output Offset Current	I_{OUTOS}	3-wire operation		–25	–35	µA
I_{OUTOS} vs. Temperature	dI_{OUTOS}/dT	3-wire operation		16	26	nA/°C
Output Offset Current	I_{OUTOS}	2-wire operation		9.5	14	µA
I_{OUTOS} vs. Temperature	dI_{OUTOS}/dT	2-wire operation		6	8	nA/°C
Output Control Current	I_{OUTC}	2-wire operation, V_{R0}/100mV		6	8	µA
I_{OUTC} vs. Temperature	dI_{OUTC}/dT	2-wire operation		–10	–15	nA/°C
Output Voltage Range	V_{OUT}	$V_{OUT} = R_L I_{OUT}$, $V_{CC} < 18V$	0		$V_{CC} - 6$	V
	V_{OUT}	$V_{OUT} = R_L I_{OUT}$, $V_{CC} \geq 18V$	0		12	V
Output Current Range FS	I_{OUTFS}	$I_{OUT} = V_{R0}/R_0$, 3-wire operation		20		mA
Output Resistance	R_{OUT}		0.5	1.0		MΩ
Load Capacitance	C_L		0		500	nF
SET Stage						
Internal Gain	G_{SET}			0.5		
Input Voltage	V_{SET}		0		1.15	V
Offset Voltage	V_{OS}			±0.5	±1.5	mV
V_{OS} vs. Temperature	dV_{OS}/dT			±1.6	±5	µV/°C
Input Bias Current	I_B			8	20	nA
I_B vs. Temperature	dI_B/dT			7	18	pA/°C
Protection Functions						
Voltage Limitation at R_0	V_{LIMR0}	$V_{INDAI} = 0$, $V_{R0} = G_{SET} V_{SET}$	580	635	690	mV
Protection against reverse polarity		*Ground* vs. V_S vs. V_{OUT}			35	V
		Ground vs. V_S vs. I_{OUT}			35	V
Current in the event of reverse polarity		*Ground* = 35V, $V_S = I_{OUT} = 0$		4.5		mA
System Parameters						
Nonlinearity		Ideal input		0.05	0.15	%FS

* In 2-wire operation a maximum current of $I_{OUTmin} - I_{CC}$ is valid

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BOUNDARY CONDITIONS

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Sense Resistor	R_0	I_{OUTFS} = 20mA	17	27	38	□
	R	c = 20mA/I_{OUTFS}	$c \cdot 17$	$c \cdot 27$	$c \cdot 38$	□
Stabilization Resistor	R□	I_{OUTFS} = 20mA	35	40	45	□
	R□	c = 20mA/I_{OUTFS}	$c \cdot 35$	$c \cdot 40$	$c \cdot 45$	□
Load Resistance	R_L	Limitation only for 3-wire operation	0		600	□
Sum Gain Resistors	$R_1 + R_2$		20		200	k□
Sum Offset Resistors	$R_3 + R_4$		20		200	k□
V_{REF} Capacitance	C_1	Ceramic	1.9	2.2	5.0	µF
Output Capacitance	C_2	Only for 2-wire operation	90	100	250	nF
D_1 Breakdown Voltage	V_{BR}		35	50		V
T_1 Forward Current Gain	□$_F$	BCX54/55/56, for example	50	150		

DETAILED DESCRIPTION OF FUNCTIONS

AM462 is a modular, universal V/I converter and protector IC which has been specially developed for the conditioning of voltage signals referenced to ground. It is designed for both 2- and 3-wire operation in industrial applications (cf. application in Figure 8). AM462's various functions are depicted in the block diagram (Figure 2) which also illustrates how few external components are required for the operation of this particular device.

AM462 consists of several modular function blocks (operational amplifiers, voltage-to-current converters and references) which, depending on external configurations, can either be switched to one another or operated separately (see the basic circuitry in Figure 2):

1. *Operational amplifier stage* OP1 enables a positive voltage signal to be amplified. OP1 gain G_{GAIN} can be set via external resistors R_1 and R_2. Protective circuitry against overvoltage is integrated into the chip, limiting the voltage to the set value of the reference voltage. Output voltage V_{OUTAD} at pin *OUTAD* is calculated as:

$$V_{OUTAD} = V_{INP} \cdot G_{GAIN} \text{ with } G_{GAIN} = 1 + \frac{R_1}{R_2} \tag{1}$$

   where V_{INP} is the voltage at OP1's input pin *INP*.

2. The internal voltage-to-current converter (V/I converter) provides a voltage-controlled current signal at IC output *IOUT* (pin 8) which activates an external transistor T_1; this in turn supplies the actual output current I_{OUT}. To reduce power dissipation the transistor is an external component and protected against reverse polarity by an additional diode D_1. Via pin *SET* an offset current I_{SET} can be set at output *IOUT* (with the help of the internal voltage reference and an external voltage divider as shown in Figure 2, for example). External resistor R_0 permits the output current to be finely adjusted with parallel operation of current and the voltage output. For the output current provided by T_1 the following ratio applies:

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de

Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

$$I_{OUT} = \frac{V_{INDAI}}{8R_0} + I_{SET} \quad \text{with} \quad I_{SET} = \frac{V_{SET}}{2R_0} \qquad (2)$$

with V_{INDAI} the voltage at pin *INDAI* and V_{SET} the voltage at pin *SET* (V/I converter inputs)[1].

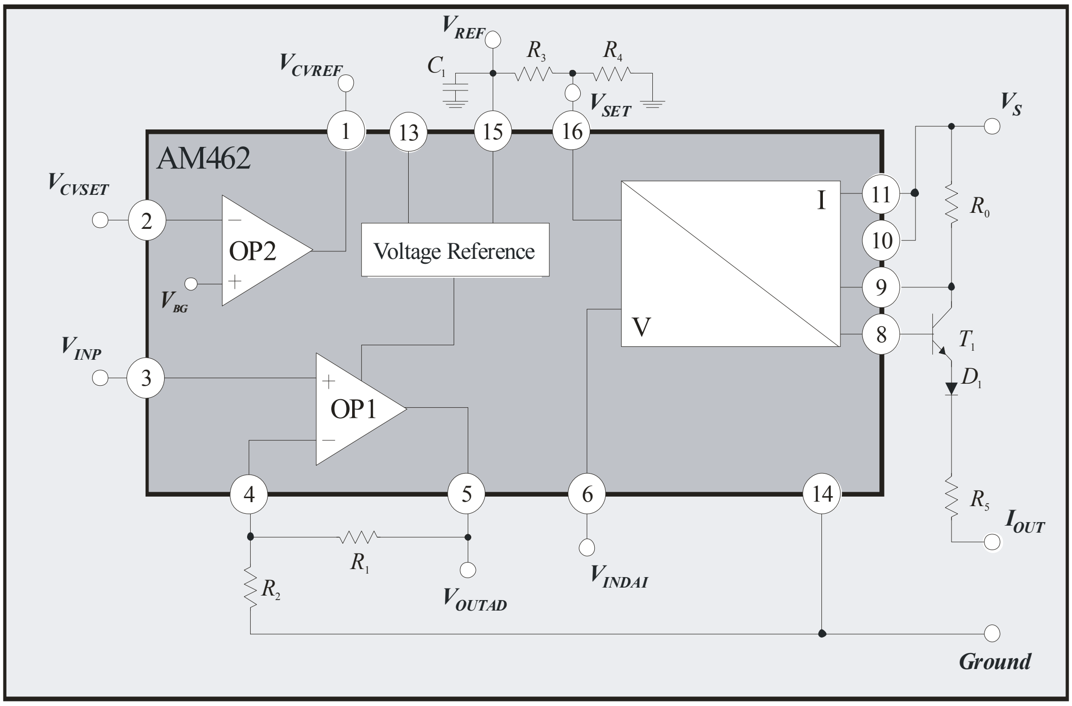

Figure 2: Block diagram of AM462 with external components (3-wire circuit for current output)

3. The AM462 *reference voltage source* enables voltage to be supplied to external components (such as sensors, microprocessors, etc.). The reference voltage value V_{REF} can be set via pin 13 *VSET*. If pin *VSET* is not connected, $V_{REF} = 5$V; if *VSET* is switched to ground, $V_{REF} = 10$V. Values between the above can be set if two external resistors are used (inserted between pin *VREF* and pin *VSET* and between pin *VSET* and *GND*; see Figure 2).

   External (ceramic) capacitor C_1 at pin *VREF* stabilizes the reference voltage. It **must** be connected even if the voltage reference is not in use.

4. The additional *operational amplifier stage* OP2 can be used as a current or voltage source to supply external components. OP2's positive input is connected internally to voltage V_{BG} so that the output current or output voltage can be set across a wide range using one or two external resistors.

[1] The construction of the V/I converter is such that output current I_{OUT} is largely independent of the current amplification β_F of external transistor T_1. Production-specific variations in the current amplification of the transistors used are compensated for internally by the V/I converter.

Analog Microelectronics GmbH
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Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
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INITIAL OPERATION OF AM462

General information on 2- and 3-wire applications and the use of current

In 3-wire operation (cf. Figure 3 right and Figure 7) the ground of the IC (pin *GND*) is connected up to the external mass of the system *Ground*. The system's supply voltage V_S is connected to pin *VCC* and pin *VCC* to pin *RS+*.

In 2-wire operation (cf. Figure 3 left and Figure 7) system supply voltage V_S is connected to pin *RS+* and pin *VCC* to *RS-*. The ground of the IC (pin *GND*) is connected to the node between resistor R_5 and load resistor R_L (current output I_{OUT}). IC ground (*GND*) is **not** the same as system ground (*Ground*)!! The output signal is picked up via load resistor R_L which connects current output I_{OUT} to the system ground.

In 2-wire operation the IC ground is "virtual" (floating), as with a constant load resistance the supply voltage of the device V_{CC} changes according to the current. As a rule, the following equation applies to 2-wire operation:

$$V_{CC} = V_S - I_{OUT}(V_{IN})\, R_L \qquad (2)$$

The reason for this is that in 2-wire operation the IC is connected in series to the actual load resistor R_L. This is illustrated in Figure 3.

In 3-wire operation $V_{CC} = V_S$, as the IC ground is connected to the ground of the system.

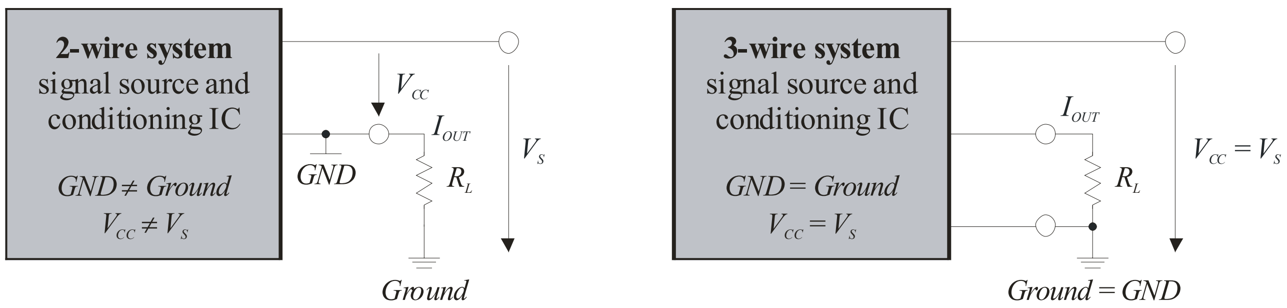

Figure 3: The difference between 2- and 3-wire operation

Setting the output current range

When using amplification stage OP1 together with the V/I converter for voltage-to-current conversion the offset of the output current should first be compensated for by suitable selection of resistors R_3 and R_4. To this end the OP1 input must be connected to ground ($V_{INP} = 0$). With the short circuit at the input and by connecting up V/I converter pin *VSET* as shown in Figure 2 the values of the output current according to Equation 2 are as follows:

$$I_{OUT}(V_{INDAI}=0)=I_{SET}=\frac{V_{REF}}{2R_0}\cdot\frac{R_4}{R_3+R_4} \tag{3}$$

and thus for the ratio of the resistors R_3/R_4:

$$\frac{R_3}{R_4}=\frac{V_{REF}}{2R_0 I_{SET}}-1 \tag{4}$$

The output current range is set in conjunction with the selected external resistors R_1 and R_2 (or fine adjustment with R_0). Using Equations 1 and 2 the following is calculated for output current I_{OUT}:

$$I_{OUT}=V_{INP}\frac{G_{GAIN}}{8R_0}+I_{SET} \quad \text{with} \quad G_{GAIN}=1+\frac{R_1}{R_2} \tag{5}$$

Selecting the supply voltage

System supply voltage V_S needed to operate AM462 is dependent on the selected mode of operation.

When using current output pin *IOUT* (in conjunction with the external transistor) the value of V_S is dependent on that of the relevant load resistor R_L (max. 600Ω) used by the application. The minimum system supply voltage V_S is then:

$$V_S \geq I_{OUT\max} R_L + V_{CC\min} \tag{6}$$

Here, $I_{OUT\max}$ stands for the maximum output current and $V_{CC\min}$ for the minimum IC supply voltage which is dependent on the selected reference voltage:

$$V_{CC\min} \geq V_{REF} + 1\text{V} \tag{7}$$

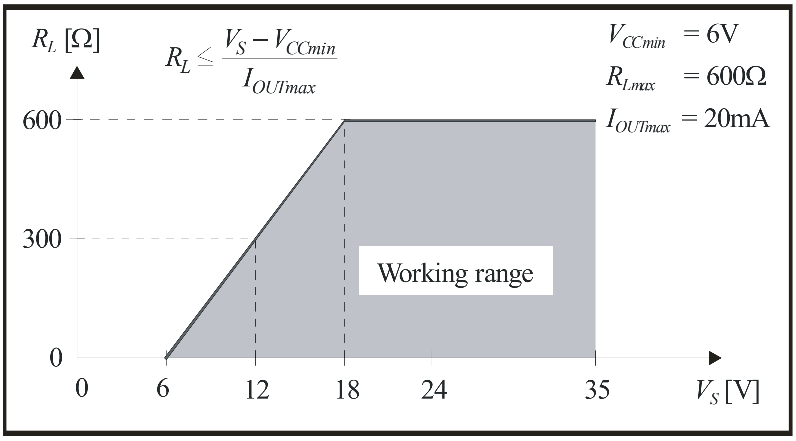

Figure 4: Working range in conjunction with the load resistor

Analog Microelectronics GmbH
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Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
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Email: info@analogmicro.de

The working range resulting from Equation 6 is described in Figure 4. Example calculations and typical values for the external components can be found in the example applications from page 13 onwards.

Using OP2 as a current source

The additional operational amplifier OP2 can easily be connected up as a constant current source. Using the circuit in Figure 5 the following applies:

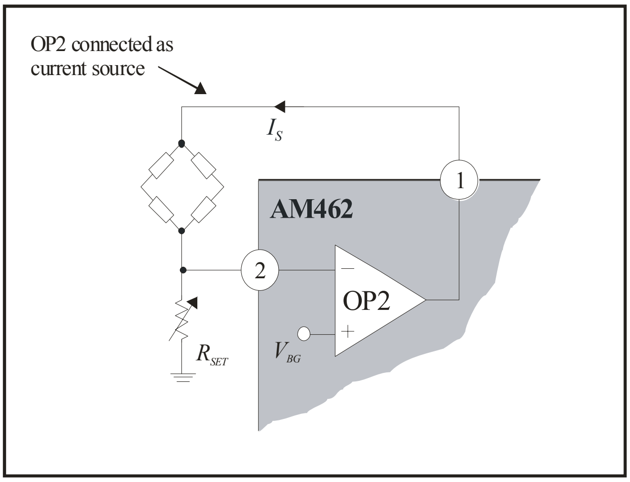

Figure 5: Using OP2 as a constant current source

Example : OP2 as courrent source

$$I_S = \frac{V_{BG}}{R_{SET}} = \frac{1.27\,\text{V}}{R_{SET}} \tag{8}$$

The bridge symbol represents the component to be supplied with current (e.g. a piezoresistive sensing element or temperature sensor).

A supply current of $I_S = 1\text{mA}$ is to be set. Using Equation 8 the following value is calculated for external resistor R_{SET}, which in turn stipulates the size of the current:

$$R_{SET} = \frac{V_{BG}}{I_S} = \frac{1.27\,\text{V}}{1\text{mA}} = 1.27\,\text{k}\Omega$$

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Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
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Using OP2 as a voltage reference

In addition to the integrated voltage reference OP2 can also be used to supply voltage to external components, such as A/D converters and microprocessors, for example. Lower voltages can be generated (e.g. 3.3V) which with the increasing miniaturization of devices and need for ever lower levels of power dissipation in digital components is today of growing importance.

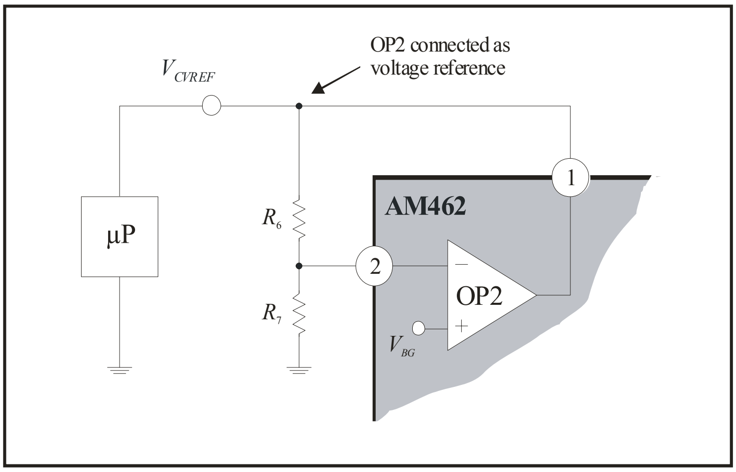

Figure 6: Using OP2 as a voltage reference

The additional operational amplifier OP2 can easily be connected up as a voltage reference. Using the circuit in Figure 6 the following applies:

$$V_{CVREF} = V_{BG}\left(1+\frac{R_6}{R_7}\right) = 1.27\,\mathrm{V}\left(1+\frac{R_6}{R_7}\right) \qquad (9)$$

Example : OP2 as voltage reference

A voltage of $V_{CVREF} =$ 3.3V is to be set. Using Equation 9 the following ratio is calculated for external resistors R_6 and R_7:

$$\frac{R_6}{R_7} = \frac{V_{CVREF}}{V_{BG}} - 1 \approx 2{,}6 - 1 = 1{,}6$$

The following example values are produced for the resistors:

$R_7 = 10\mathrm{k}\Omega$ $\qquad$ $R_6 = 16\mathrm{k}\Omega$

Analog Microelectronics GmbH
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POINTS TO NOTE: INITIAL OPERATION OF AM462

1. When operating AM462 it is imperative that external capacitor C_1 is **always** connected (cf. ***Figure 2***). Care must be taken that the value of the capacitance does not lie beyond its given range, even across the range of temperature (see *Boundary Conditions* on page 7). In 2-wire operation ceramic capacitor C_2 must also be used (cf. Figure 8).
2. In a 2-wire setup the power consumption of the overall system (AM462 plus all external components, including the configuration resistors) **must not exceed** the sum of $I_{OUT\min}$ (usually 4mA).
3. All AM462 function blocks not required by the application must be connected to a defined (and allowed) potential.
4. A load resistance of 600Ω **maximum** is permitted for the current output.
5. The values of external resistors R_0, R_1, R_2, R_3, R_4 and R_5 must be selected within the permissible range given in the boundary conditions on page 7.

APPLICATIONS

Typical 3-wire application with an input signal referenced to ground

Figure 7 shows a 3-wire application in which AM462 amplifies and converts a positive voltage signal referenced to ground. The unused blocks (e.g. OP2) have been set to defined operating points in the application. Alternatively, these function groups can also be used here (e.g. to supply external components).

For output current I_{OUT} the following applies according to Equations 1 and 2:

$$I_{OUT} = V_{INP} \cdot \frac{G_I}{8R_0} + I_{SET} \quad \text{with} \quad G_I = G_{GAIN} = 1 + \frac{R_1}{R_2}$$

Example: 0…20mA Voltage-To-Current Transmitter

To obtain a signal of $V_{INP} = 0...1V$ at the OP1 input the external components are to be dimensioned in such a way that the output current has a range of 0...20mA (i.e. $I_{SET} = 0 \Rightarrow SET = GND$). With $R_0 = 27\Omega$:

$$I_{OUT} = V_{INP} \cdot \frac{G_I}{8R_0} + I_{SET} = V_{INP} \cdot \frac{G_{GAIN}}{8R_0}$$

The following then applies to the gain:

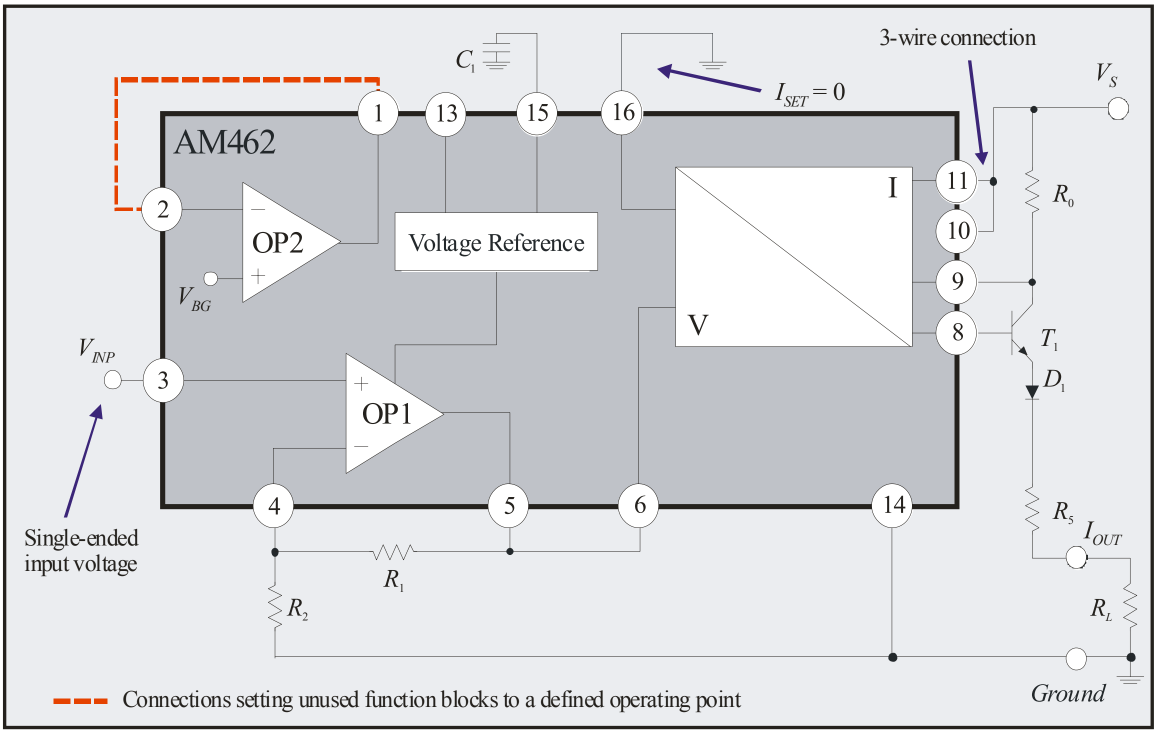

Figure 7: Typical application for input signals referenced to ground

$$G_{GAIN} = 8R_0 \frac{I_{OUT}}{V_{INP}} = 8 \cdot 27\Omega \cdot \frac{20\text{mA}}{1\text{V}} \approx 4.32 \quad \Rightarrow \quad \frac{R_1}{R_2} = 4.32 - 1 = 3.32$$

Observing the boundary conditions (page 7), the following values are obtained for the external components:

$R_1 \approx 33.2\text{k}\Omega$ $R_2 = 10\text{k}\Omega$ $R_0 = 27\Omega$ $R_5 = 39\Omega$ $R_L = 0...600\Omega$ $C_1 = 2.2\mu\text{F}$

Typical 2-wire application with an input signal referenced to ground

In 2-wire operation (cf. Figure 8) system supply voltage V_S is connected up to pin *RS+* and pin *VCC* to pin *RS-*. The ground of the IC (pin *GND*) is connected to the node between resistor R_5 and load resistor R_L. IC ground (*GND*) is **not** the same as system ground (*Ground*). The output signal is picked up via load resistor R_L which connects current output I_{OUT} to the system ground.

It must be ensured that in 2-wire operation an additional current load (use of current/voltage source) is limited to 4mA due to the domestic current supply and limitation.

For output current I_{OUT} the following applies according to Equations 1 and 2:

$$I_{OUT} = V_{INP} \cdot \frac{G_I}{8R_0} + I_{SET} \quad \text{with} \quad G_I = G_{GAIN} = 1 + \frac{R_1}{R_2} \quad \text{and} \quad I_{SET} = \frac{V_{REF}}{2R_0} \cdot \frac{R_4}{R_3 + R_4}$$

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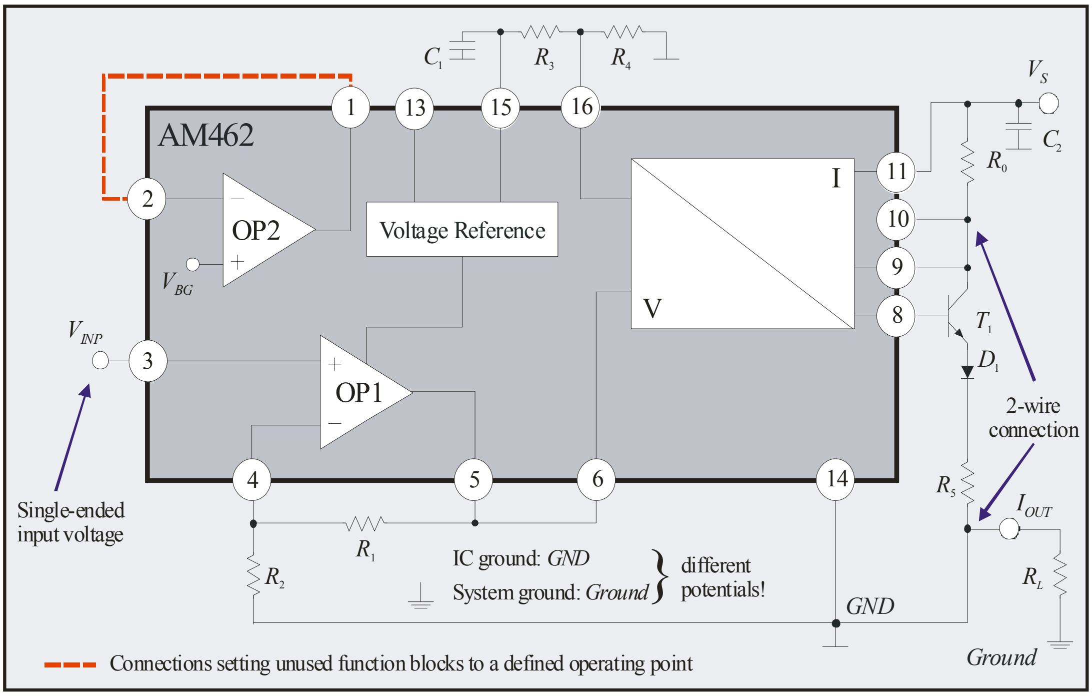

Figure 8: Typical 2-wire operation for input signals referenced to ground

Example : 4…20mA Voltage-To-Current Transmitter

To obtain a signal of V_{INP} = 0...1V at the OP1 input the external components are to be dimensioned in such a way that the output current has a range of 4...20mA. The following applies:

$$I_{OUT} = V_{INP} \cdot \frac{G_I}{8R_0} + I_{SET} = V_{INP} \cdot \frac{G_{GAIN}}{8R_0} + 4\text{mA}$$

With $R_0 = 27\Omega$ and $I_{SET} = 4\text{mA}$ Equation 4 produces the following for resistors R_3 and R_4:

$$\frac{R_3}{R_4} = \frac{V_{REF}}{2R_0 I_{SET}} - 1 = \frac{5\text{V}}{2 \cdot 27\Omega \cdot 4\text{mA}} - 1 \approx 22.15$$

and thus the following value for the gain:

$$G_{GAIN} = 8R_0 \frac{I_{OUT\,\max} - I_{SET}}{V_{INP}} = 8 \cdot 27\Omega \cdot \frac{16\text{mA}}{1\text{V}} = 3.456 \quad \Rightarrow \quad \frac{R_1}{R_2} = 3.456 - 1 = 2.456$$

Observing the given boundary conditions, the following values are obtained for the external components:

$R_1 \approx 24.56\text{k}\Omega$	$R_2 = 10\text{k}\Omega$	$R_3 \approx 44.3\text{k}\Omega$	$R_4 = 2\text{k}\Omega$	
$R_0 = 27\Omega$	$R_5 = 39\Omega$	$R_L = 0...600\Omega$	$C_1 = 2.2\mu\text{F}$	$C_2 = 100\text{nF}$

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

Application for an input signal with an offset

It is not uncommon for input signals to have an offset (e.g. of 0.5...4.5V or 1...6V). For signals such as these an offset current is generated at the IC output also when $I_{SET} = 0$. The circuit can then be dimensioned as described in the following.

According to Equation 2 the following applies for a required current swing at the output of $\Delta I_{OUT} = I_{OUT\max} - I_{OUT\min}$:

$$\Delta I_{OUT} = \frac{\Delta V_{PIN6}}{8R_0} \quad \Rightarrow \quad \Delta V_{PIN6} = 8R_0 \Delta I_{OUT} \tag{10}$$

For an input current swing of $\Delta V_{IN} = V_{IN\max} - V_{IN\min}$ the necessary gain is calculated as:

$$G = \frac{\Delta V_{PIN6}}{\Delta V_{IN}} \tag{11}$$

If $G < 1$, the input signal can be routed directly to pin 6 (*INDAI*) via a voltage divider without OP1 having to be used (see Figure 9). With this circuitry the following results:

$$G = \frac{\Delta V_{PIN6}}{\Delta V_{IN}} = \frac{R_9}{R_8 + R_9} \quad \Rightarrow \quad \frac{R_8}{R_9} = \frac{\Delta V_{IN}}{\Delta V_{PIN6}} - 1 \tag{12}$$

From input offset $V_{IN\min}$ the following output current is then obtained when $I_{SET} = 0$:

$$I_{OUT}(V_{IN\min}) = V_{IN\min} \cdot \frac{R_9}{R_8 + R_9} \cdot \frac{1}{8R_0} \tag{13}$$

Using the *SET* pin and Equation 2 the required minimum output current $I_{OUT\min}$ can then be set:

$$I_{OUT} = V_{IN} \cdot \frac{R_9}{R_8 + R_9} \cdot \frac{1}{8R_0} + I_{SET} \quad \text{with} \quad I_{SET} = \frac{V_{REF}}{2R_0} \cdot \frac{R_4}{R_3 + R_4} \tag{14}$$

Example : 4..20mA Voltage-To-Current Transmitter with Input Signal Offset

To obtain a signal of $V_{IN} = 0.5...4.5\text{V}$ the external components are to be dimensioned in such a way that the output current has a range of 4...20mA. The circuitry is shown in Figure 9. OP1 is not used here. It is, however, available to the user as an additional OP and can be used as an impedance converter at the voltage-to-current converter input *INDAI*, for example.

With reference to Equation 10 and with $R_0 = 27\Omega$, a voltage swing is obtained at pin 6 of:

$$\Delta V_{PIN6} = 8R_0 \Delta I_{OUT} = 8 \cdot 27\Omega \cdot 16\text{mA} = 3.456\text{V}$$

Using Equation 12 the following applies:

$$\frac{R_8}{R_9} = \frac{\Delta V_{IN} - \Delta V_{PIN6}}{\Delta V_{PIN6}} = \frac{4\text{V} - 3.456\text{V}}{3.456\text{V}} \approx 0.157 \quad \Rightarrow \quad R_9 = 6.35 \cdot R_8$$

Analog Microelectronics GmbH
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Phone: +49 (0)6131/91 073 - 0
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Email: info@analogmicro.de

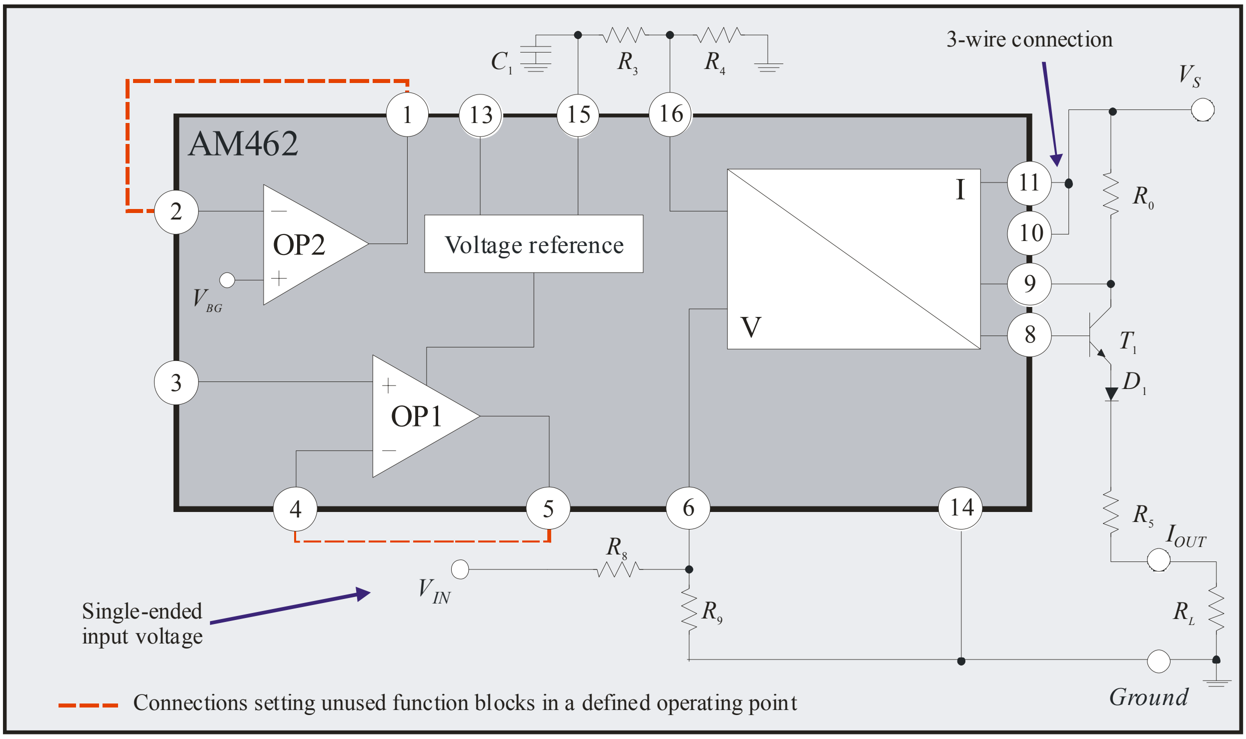

Figure 9: Converting an input signal with an

According to Equation 13 the minimum output current generated by the input offset is calculated as:

$$I_{OUT\,\min} = V_{IN\,\min} \cdot \frac{R_9}{R_8 + R_9} \cdot \frac{1}{8R_0} = 0.5\text{V} \cdot \frac{6{,}37}{6.37+1} \cdot \frac{1}{8 \cdot 27\Omega} \approx 2\text{mA}$$

To obtain an output current of I_{OUT} = 4...20mA, according to the above a current of I_{SET} = 2mA must then be added. With reference to Equation 4 the ratio of R_3 to R_4 is calculated thus:

$$I_{SET} \overset{!}{=} 2\text{mA} = \frac{V_{REF}}{2R_0} \cdot \frac{R_4}{R_3 + R_4} \quad \Rightarrow \quad \frac{R_3}{R_4} = \frac{V_{REF}}{2R_0 I_{SET}} - 1 = \frac{5\text{V}}{2 \cdot 27\Omega \cdot 2\text{mA}} - 1 \approx 45.3$$

Observing the given boundary conditions, the following values are obtained for the external components:

$R_0 \approx= 27\Omega$	$R_8 \approx 10\text{k}\Omega$	$R_9 = 63.7\text{k}\Omega$	$R_3 = 90.6\text{k}\Omega$	$R_4 = 2\text{k}\Omega$
$R_5 = 39\Omega$	$R_L = 0...600\Omega$	$C_1 = 2.2\mu\text{F}$		

Industrial V/I Converter and Protector IC
AM462

BLOCK DIAGRAM AND PINOUT

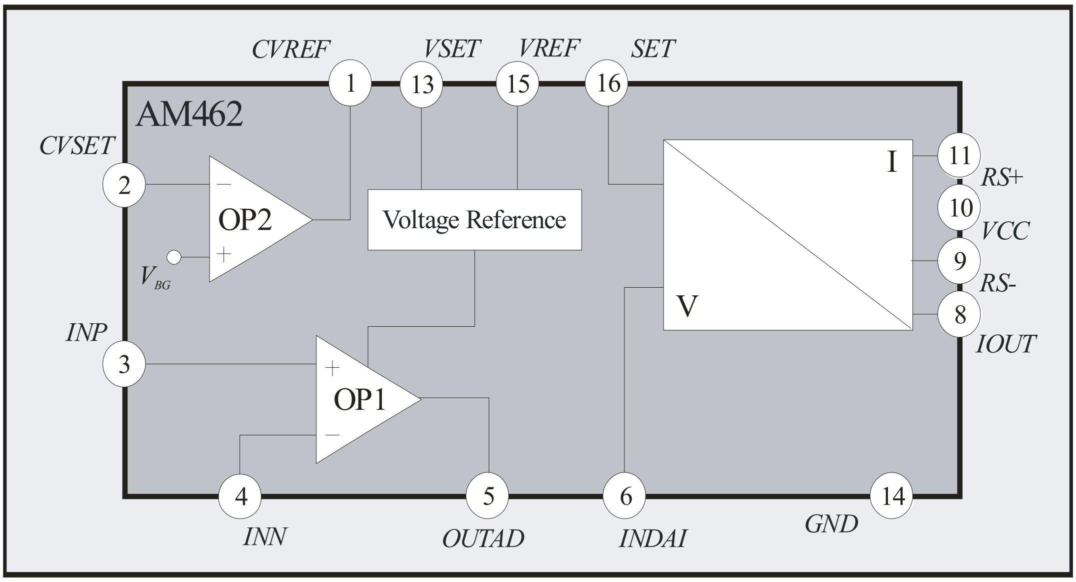

Figure 10: Block diagram of AM462

PIN	NAME	EXPLANATION
1	*CVREF*	Current/Voltage reference
2	*CVSET*	Current/Voltage reference set
3	*INP*	Positive input
4	*INN*	Negative input
5	*OUTAD*	System amplification output
6	*INDAI*	Current output stage input
7	*N.C.*	Not connected
8	*IOUT*	Current output
9	*RS–*	Sensing resistor -
10	*VCC*	Supply voltage
11	*RS+*	Sensing resistor +
12	*N.C.*	Not connected
13	*VSET*	Reference voltage source set
14	*GND*	IC ground
15	*VREF*	Reference voltage source output
16	*SET*	Output offset current set

Table 1: AM462 Pin out

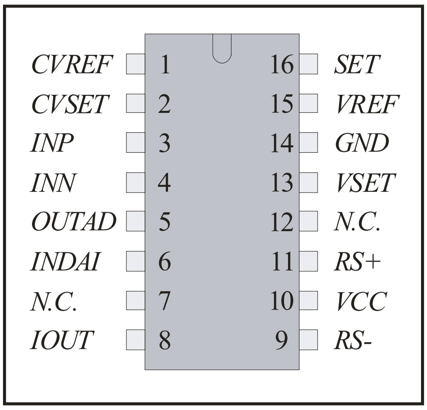

Figure 11: AM462 Pin out

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

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AM462

EXAMPLE APPLICATIONS

- ***Application as a voltage-to-current converter IC***

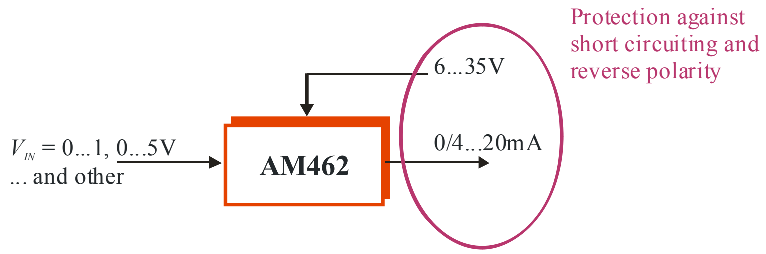

Figure 12: Application as a current converter IC

- ***Converting a 0.5...4.5V sensor (voltage) signal***

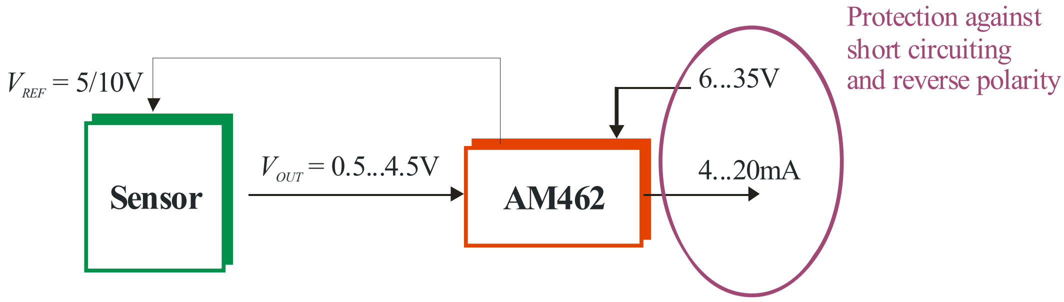

Figure 13: Converting a 0.5...4.5V sensor signal

- ***Configuration as a peripheral processor IC*** **[2]**

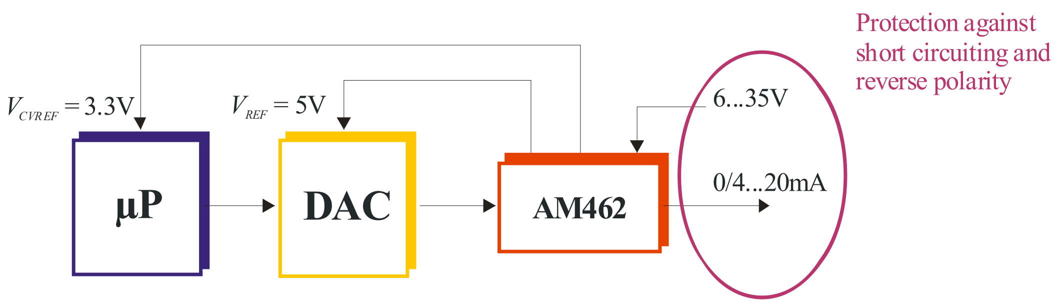

Figure 14: Configuration as a peripheral processor IC and supply unit

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de
Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de

- ***Application as an analog output IC and supply unit for sensors***

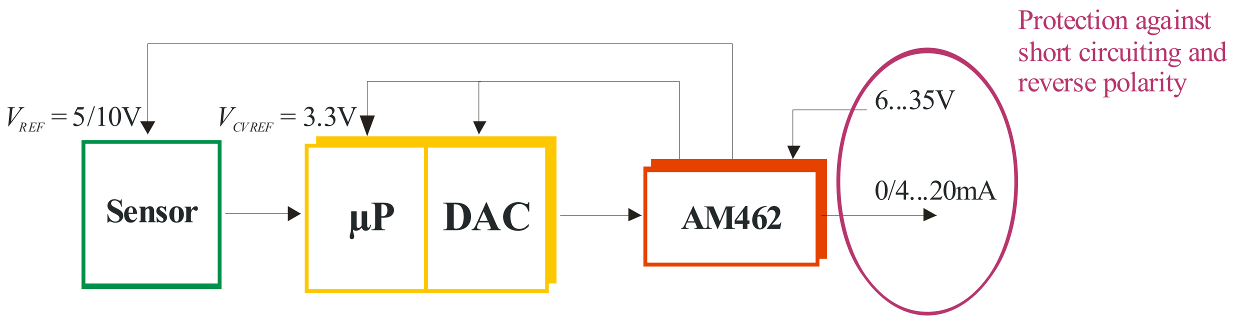

Figure 15: Output IC and supply unit in sensor applications

- ***Application as a front-end and back-end IC for microprocessors***

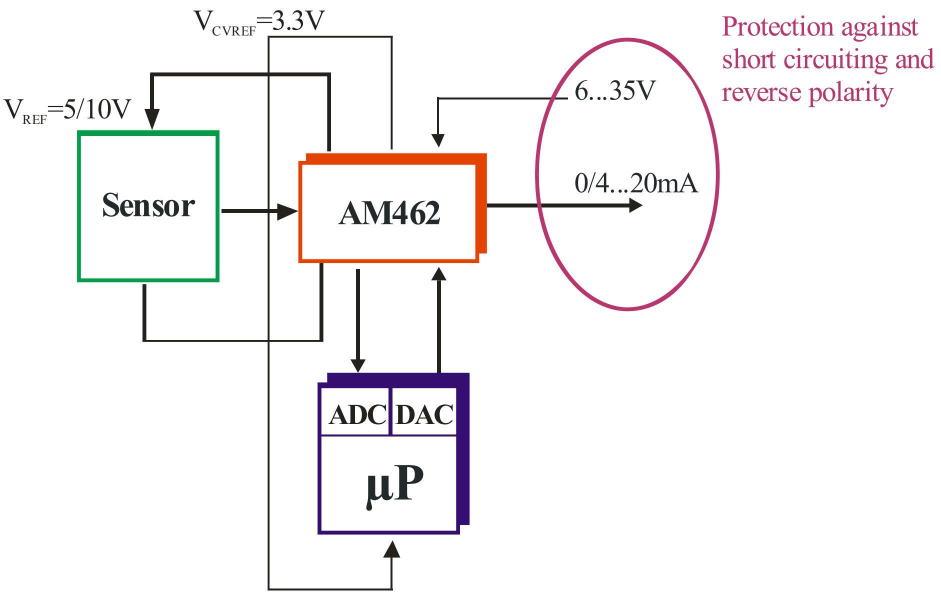

Figure 16: Application as an analog front end and back end for microprocessors (Frame ASIC concept)

Analog Microelectronics GmbH Phone: +49 (0)6131/91 073 - 0
An der Fahrt 13, D – 55124 Mainz Fax: +49 (0)6131/91 073 – 30
Internet: http://www.analogmicro.de Email: info@analogmicro.de

Industrial V/I Converter and Protector IC
AM462

DELIVERY

The AM462 V/I converter and protector IC is available as the following packages:

- SSOP16
- SO16(n)
- Dice on 5" blue foil (on request)

PACKAGE DIMENSIONS

Please see our website (data sheets: package.pdf).

FURTHER READING

www.analogmicro.de

[1] The Frame ASIC concept: See:

[2] The AM462 can be used as an integrated solution to interface a microprocessor to the industrial 4...20mA network. See: Technical Articles: PR1011 and

Interfacing the µProcessor with the 4...20mA current loop signal (PLC). See: Application notes AN1014.

NOTES

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Internet: http://www.analogmicro.de

Phone: +49 (0)6131/91 073 - 0
Fax: +49 (0)6131/91 073 – 30
Email: info@analogmicro.de