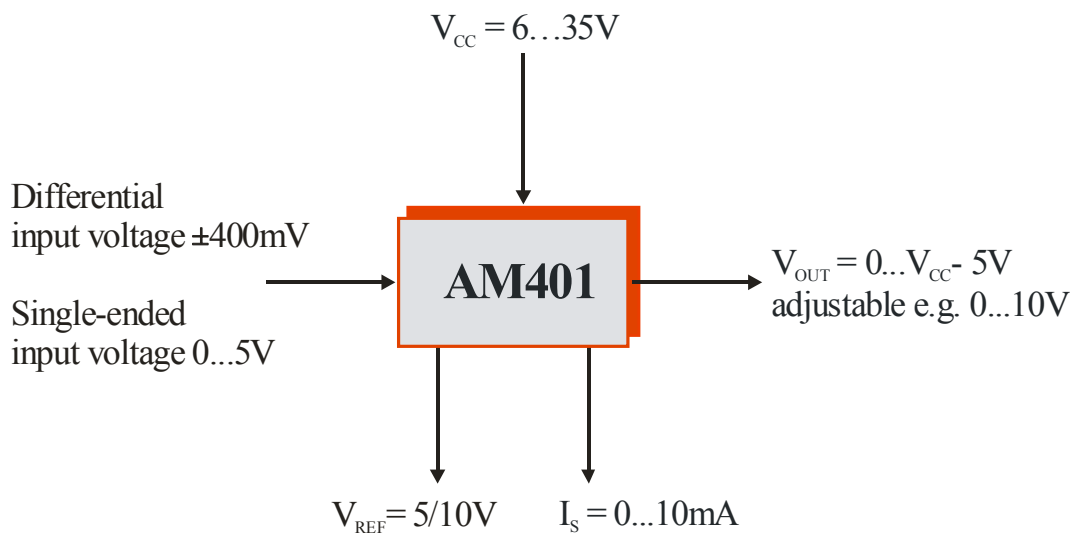


# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### PRINCIPLE FUNCTION

**Amplification and conversion of differential signals referenced to ground to adjustable industrial voltages (0... $V_{CC}$ -5V, e.g. 0...5/10V etc.)**  
**Variable current/voltage source and integrated protective circuitry**



### TYPICAL APPLICATIONS

- Transducer for sensor applications, for example
- Analog output stage for microprocessors
- Impedance converter
- Voltage regulator with voltage and current sources
- Analog front-end and back-end IC (Frame ASIC concept [1])
- Adjustable output stage IC

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

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# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### FEATURES

- Supply voltage range: 6...35V
- Wide operating temperature range:  $-40^{\circ}\text{C} \dots +85^{\circ}\text{C}$
- Adjustable voltage reference: 5 to 10V
- Additional current/voltage source
- Instrumentation amplifier input CMVI:  $1.5 \dots V_{\text{CC}} - 3\text{V}$
- Operational amplifier input Vin:  $0 \dots V_{\text{CC}} - 5\text{V}$
- Adjustable gain and offset
- Adjustable output voltage range:  $0 \dots V_{\text{CC}} - 5\text{V}$ , e.g. 0.5...4.5V, 0...5/10V
- Individually configurable function modules
- Protection against reverse polarity
- Output current limitation
- Short-circuit protection
- Protection against ESD
- RoHS compliant

### GENERAL DESCRIPTION

AM401 and AM401P [2] are universal voltage transmitters designed for differential bridge signal conditioning. The two devices differ in their offset and offset drift values. The ICs are modular and their functional units individually accessible. Both ICs consist of a high-precision instrumentation amplifier for differential input signals and an operational amplifier for input signals referenced to ground. A robust reference voltage source (adjustable between 5 and 10V) can be used to power external components. An operational amplifier stage whose gain is also adjustable acts as an output. The devices also contain an additional operational amplifier which can be used as a current or voltage source. The IC is protected against reverse polarity and has an integrated output current limit. Standard industrial voltages (e.g. 0–5/10V, 0.5–4.5V) can be easily generated using transmitter ICs AM401 and AM401P.

### BLOCK DIAGRAM

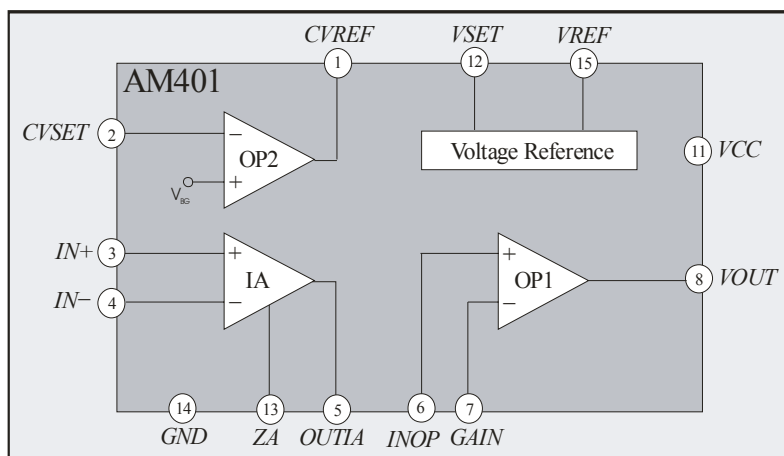


Figure 1: Block diagram of AM401 (individually configurable function)

# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### ELECTRICAL SPECIFICATIONS

$T_{amb} = 25^{\circ}\text{C}$ ,  $V_{CC} = 24\text{V}$ ,  $V_{REF} = 5\text{V}$ ,  $I_{REF} = 1\text{mA}$  (unless otherwise stated)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Voltage Range	$V_{CC}$		6		35	V
Quiescent Current	$I_{CC}$	$T_{amb} = -40\dots+85^{\circ}\text{C}$ , $I_{REF} = 0\text{mA}$			1.5	mA
<b>Temperature Specifications</b>						
Operating	$T_{amb}$		-40		85	$^{\circ}\text{C}$
Storage	$T_{st}$		-55		125	$^{\circ}\text{C}$
Junction	$T_J$				150	$^{\circ}\text{C}$
Thermal Resistance	$\Theta_{ja}$	DIL16 plastic package		70		$^{\circ}\text{C}/\text{W}$
	$\Theta_{ja}$	SSOP plastic package		120		$^{\circ}\text{C}/\text{W}$
	$\Theta_{ja}$	SO16 narrow plastic package		140		$^{\circ}\text{C}/\text{W}$
<b>Voltage Reference</b>						
Voltage	$V_{REF}$	$V_{SET}$ not connected	4.90	5.00	5.10	V
	$V_{REF}$	$V_{SET} = GND$ , $V_{CC} \geq 11\text{V}$	9.8	10.0	10.2	V
Current	$I_{REF}$		0.2		10.0	mA
$V_{REF}$ vs. Temperature	$dV_{REF}/dT$	$T_{amb} = -40\dots+85^{\circ}\text{C}$		$\pm 90$	$\pm 140$	ppm/ $^{\circ}\text{C}$
Line Regulation	$dV_{REF}/dV$	$V_{CC} = 6\text{V}\dots 35\text{V}$		30	80	ppm/V
	$dV_{REF}/dV$	$V_{CC} = 6\text{V}\dots 35\text{V}$ , $I_{REF} \approx 5\text{mA}$		60	150	ppm/V
Load Regulation	$dV_{REF}/dI$			0.05	0.10	%/mA
	$dV_{REF}/dI$	$I_{REF} \approx 5\text{mA}$		0.06	0.15	%/mA
Load Capacitance	$C_L$		1.9	2.2	5.0	$\mu\text{F}$
<b>Current/Voltage Source (OP2)</b>						
Internal Reference	$V_{BG}$		1.20	1.27	1.35	V
$V_{BG}$ vs. Temperature	$dV_{BG}/dT$	$T_{amb} = -40\dots+85^{\circ}\text{C}$		$\pm 60$	$\pm 140$	ppm/ $^{\circ}\text{C}$
Current Source: $I_{CV} = V_{BG}/R_{EXT}$ (see page 10 for details)						
Adjustable Current Range	$I_{CV}$		0		10	mA
Output Voltage	$V_{CV}$	$V_{CC} < 18\text{V}$	$V_{BG}$		$V_{CC} - 5$	V
	$V_{CV}$	$V_{CC} \geq 18\text{V}$	$V_{BG}$		13	V
Voltage Source: $V_{CV} = V_{BG}(1+R_4/R_3)$ (see page 13 for details)						
Adjustable Voltage Range	$V_{CV}$	$V_{CC} < 18\text{V}$	0.4		$V_{CC} - 5$	V
	$V_{CV}$	$V_{CC} \geq 18\text{V}$	0.4		13	V
Output Current	$I_{CV}$	Source			10	mA
	$I_{CV}$	Sink			-100	$\mu\text{A}$
Load Capacitance	$C_L$	Source mode	0	1	10	nF

# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### ELECTRICAL SPECIFICATIONS

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
<b>Instrumentation Amplifier (IA) AM401</b>						
Internal Gain	$G_{IA}$		4.9	5	5.1	
Differential Input Voltage Range	$V_{IN}$		0		$\pm 400$	mV
Common Mode Input Range	$CMIR$	$V_{CC} < 9V, I_{CV} < 2mA$	1.5		$V_{CC} - 3$	V
	$CMIR$	$V_{CC} \geq 9V, I_{CV} < 2mA$	1.5		6.0	V
Common Mode Rejection Ratio	$CMRR$		80	90		dB
Power Supply Rejection Ratio	$PSRR$		80	90		dB
Offset Voltage	$V_{OS}$			$\pm 1.5$	$\pm 6$	mV
$V_{OS}$ vs. Temperature	$dV_{OS}/dT$			$\pm 5$		$\mu V/^{\circ}C$
Input Bias Current	$I_B$			-120	-300	nA
$I_B$ vs. Temperature	$dI_B/dT$			-0.35	-0.8	nA/ $^{\circ}C$
Output Voltage Range*	$V_{OUTIA}$	$V_{CC} < 9V, R_{LLA} \leq 10k\Omega$	0*		$V_{CC} - 3$	V
	$V_{OUTIA}$	$V_{CC} \geq 9V, R_{LLA} \leq 10k\Omega$	0*		6	V
Minimum Output Voltage	$V_{OUTIAmin}$	Without external load resistance $R_{LLA}$		5	17	mV
Load Capacitance	$C_L$				250	pF
<b>Instrumentation Amplifier (IA) AM401P</b>						
Internal Gain	$G_{IA}$		4.9	5	5.1	
Differential Input Voltage Range	$V_{IN}$		0		$\pm 400$	mV
Common Mode Input Range	$CMIR$	$V_{CC} < 9V, I_{CV} < 2mA$	1.5		$V_{CC} - 3$	V
	$CMIR$	$V_{CC} \geq 9V, I_{CV} < 2mA$	1.5		6.0	V
Common Mode Rejection Ratio	$CMRR$		80	90		dB
Power Supply Rejection Ratio	$PSRR$		80	90		dB
Offset Voltage	$V_{OS}$				$\pm 1,5$	mV
$V_{OS}$ vs. Temperature	$dV_{OS}/dT$				$\pm 5$	$\mu V/^{\circ}C$
Input Bias Current	$I_B$			-120	-300	nA
$I_B$ vs. Temperature	$dI_B/dT$			-0.35	-0.8	nA/ $^{\circ}C$
Output Voltage Range*	$V_{OUTIA}$	$V_{CC} < 9V, R_{LLA} \leq 10k\Omega$	0*		$V_{CC} - 3$	V
	$V_{OUTIA}$	$V_{CC} \geq 9V, R_{LLA} \leq 10k\Omega$	0*		6	V
Minimum Output Voltage	$V_{OUTIAmin}$	Without external load resistance $R_{LLA}$		5	17	mV
Load Capacitance	$C_L$				250	pF
<b>Zero Adjust Stage (IA)</b>						
Internal Gain	$G_{ZA}$			1		
Input Voltage	$V_{ZA}$	$V_{ZA} \leq V_{OUTIA} - G_{IA} V_{IN}$	0		$V_{OUTIA}$	V
Offset Voltage	$V_{OS}$			$\pm 0.5$	$\pm 2.0$	mV
$V_{OS}$ vs. Temperature	$dV_{OS}/dT$			$\pm 1.6$	$\pm 5$	$\mu V/^{\circ}C$
Input Bias Current	$I_B$			38	100	nA
$I_B$ vs. Temperature	$dI_B/dT$			24	75	pA/ $^{\circ}C$

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## ELECTRICAL SPECIFICATIONS

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
<b>Voltage Output Stage (OP1)</b>						
Adjustable Gain	$G_{OP}$		1			
Input Range	$I_R$	$V_{CC} < 10V$	0		$V_{CC} - 5$	V
		$V_{CC} \geq 10V$	0		5	V
Power Supply Rejection Ratio	$PSRR$		80	90		dB
Offset Voltage	$V_{OS}$			$\pm 0.5$	$\pm 2$	mV
$V_{OS}$ vs. Temperature	$dV_{OS}/dT$			$\pm 3$	$\pm 7$	$\mu V/^\circ C$
Input Bias Current	$I_B$			5	12	nA
$I_B$ vs. Temperature	$dI_B/dT$			3.5	10	$pA/^\circ C$
Output Voltage Range	$V_{OUT}$	$V_{CC} < 18V$	0		$V_{CC} - 5$	V
		$V_{CC} \geq 18V$	0		13	V
Output Current Limitation	$I_{LIM}$	$V_{OUT} \geq 10V$	5	7	10	mA
Output Current	$I_{OUT}$		0		$I_{LIM}$	mA
Load Resistance	$R_L$		2			k $\Omega$
Load Capacitance	$C_L$				500	nF
<b>Protection Functions</b>						
Protection against reverse polarity		Ground vs. $V_S$ vs. $V_{OUT}$ $R_I \geq 20$ k $\Omega$			35	V
Output current limitation	$I_{LIM}$	$V_{OUT} \geq 10V$			10	mA
<b>System Parameters</b>						
Nonlinearity		Ideal input		0.05	0.15	%FS

\* Depending on external load resistance at output IA ( $R_{LIA} \leq 10k\Omega \Rightarrow V_{OUTIA} < 3mV$ ); internal load resistance is  $\approx 100k\Omega$   
Currents flowing into the IC are negative

## BOUNDARY CONDITIONS

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Sum Gain Resistors	$R_1 + R_2$		90		200	k $\Omega$
Sum Reference Adjustment Resistors	$R_3 + R_4$		20		200	k $\Omega$
Stabilization Capacitance @ $V_{REF}$	$C_1$		1.9	2.2	5.0	$\mu F$
$V_{IA}$ Capacitance	$C_2$		10		100	pF

### IMPORTANT CONDITION:

\*The reference output always has to source 1mA.

# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### DETAILED DESCRIPTION OF FUNCTIONS

AM401 is a monolithically integrated voltage transmitter which has been designed for the conditioning of differential bridge voltages and for the conversion of voltage signals referenced to ground. By varying just a few external components the output voltage can be adjusted over a wide range. All of the function blocks are individually accessible, enabling them to be used as functional units or, using the relevant external circuitry, configured as an application-specific device. Typical applications and values for external components are given in the examples described in the following.

In essence AM401 consists of 4 functional blocks as shown in Figure 1. The individual blocks are as follows:

1. The core element of AM401 is its high-precision *instrumentation amplifier* (IA) with an internal gain of  $G_{IA}$  and the ability to set the reference potential of the amplifier externally (pin  $Z_A$ ). The IA acts as an input stage for differential voltage signals.
2. There is also an *operational amplifier stage* (OP1). OP1's gain of  $G_{OP1}$  can be set using external resistors  $R_1$  and  $R_2$  (see Figure 2). The operational amplifier output has been designed in such a way that with certain loads it can be set down to zero. In addition, the output stage can drive up to a maximum of 10mA without an external transistor having to be connected. An output current limit has been implemented as a protective feature which guards the IC at the output in the event of a short-circuit.
3. AM401's *voltage reference* permits voltage to be supplied by external components (such as sensors, microprocessors, etc.). The reference voltage  $V_{REF}$  has a value of either 5V or 10V. External capacitance  $C_1$  acts as a reference voltage stabilizer. It **must** also be connected when the voltage reference is not in use (see: Figure 2).
4. An additional *operational amplifier* (OP2) can be used as a current or voltage source for the supply of external components. OP2's positive input is connected internally to voltage  $V_{BG}$  so that the output current or voltage can be set across a wide range using one or two external resistors. Descriptions of the relevant applications can be found on the following pages. The operational amplifier output has a sufficiently high drive power.

One of AM401's main features is its range of integrated protective circuits which make the IC an effective output stage.

- Pins  $V_{OUT}$ ,  $V_{CC}$  and  $GND$  are protected against reverse polarity across the entire supply voltage range without the need for any additional external components.
- The output of the IC is protected against short-circuiting.
- All pins (with the exception of  $V_{OUT}$ ,  $V_{CC}$  and  $GND$ ) are protected by internal ESD diodes.

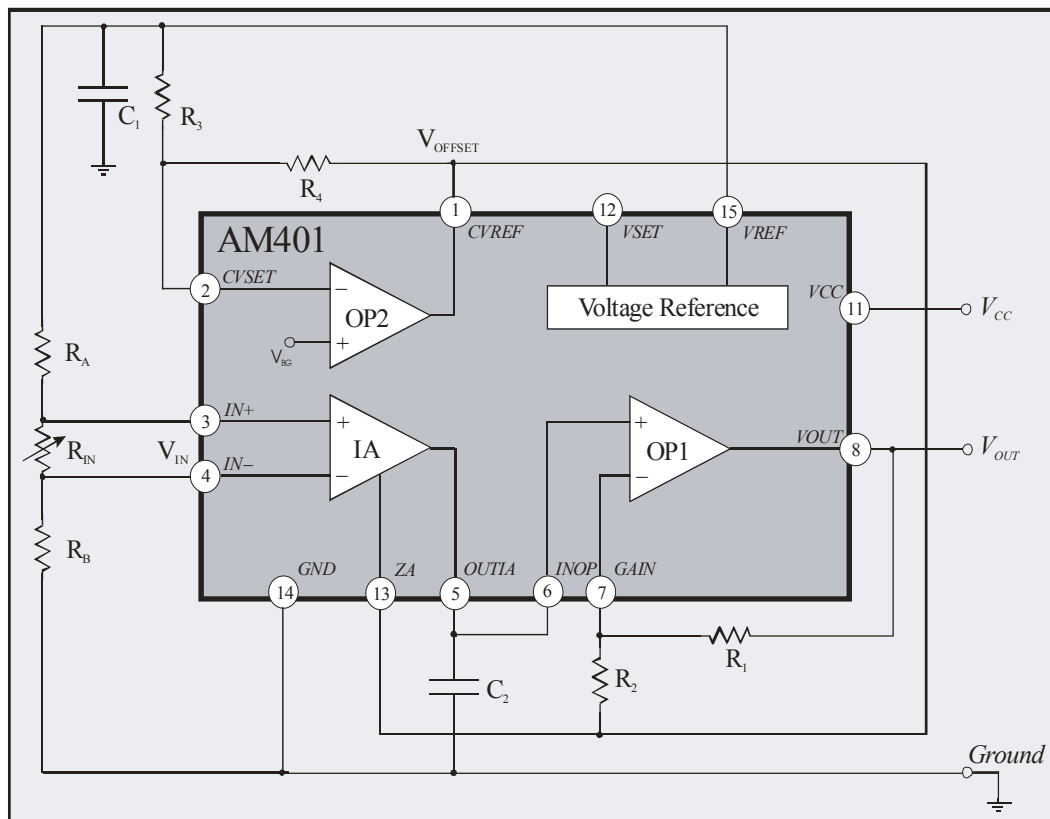
# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## AM401's transfer function

In compliance with Figure 2 the transfer function for AM401 when used as an amplifier for differential signals with a voltage output is:

$$V_{OUT} = G_{OP}(G_{IA}V_{IN} + V_{ZA}) \quad (1)$$

where:  $G = G_{IA}G_{OP} = G_{IA}(1 + R_1/R_2)$  (2)



**Figure 2:** The general functions of AM401

## Setting the instrumentation amplifier

The transfer function of the instrumentation amplifier is determined by:

$$V_{OUTIA} = G_{IA}V_{IN} + V_{ZA}$$

with an offset voltage of  $V_{ZA}$  which can be set at pin ZA. With the circuitry shown in Figure 2 and using the additional operational amplifier the offset voltage is determined thus:



# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

$$V_{OFFSET} = V_{BG} - \frac{R_A}{R_3} (V_{REF} - V_{BG}) \quad (3)$$

The following applies to the IC's actual output voltage  $V_{OUT}$  (transfer function of OP1):

$$V_{OUT} = G_{OP} \cdot V_{INOP} \quad (4)$$

with an adjustable gain of  $G_{OP}$ :  $G_{OP} = \frac{R_1}{R_2} + 1$  (5)

## Setting the voltage amplification

The gain of operational amplifier stage OP1 can be set using the suitably selected external resistors  $R_1$  and  $R_2$ . If OP1 is connected up as a non-inverting amplifier (see: Figure2) output voltage  $V_{OUT}$  at pin  $V_{OUT}$  is calculated as follows:

$$V_{OUT} = V_{IN} \cdot G_{OP1} \text{ with } G_{OP1} = \frac{R_1}{R_2} + 1$$

where  $V_{IN}$  is the voltage at OP1's input pin  $INOP$ .

## Selecting the supply voltage

In principle AM401 can be used across the entire supply voltage range defined herein. However, depending on the output voltage selected and the circuitry of the remaining components certain boundary conditions apply when selecting  $V_{CC}$ :

- When using voltage output pin  $V_{OUT}$  the IC's minimum supply voltage  $V_{CC}$  necessary for the operation of the device depends on the maximum output voltage  $V_{OUTmax}$  required by the application. The following applies:

$$V_{CC} \geq V_{OUTmax} + 5V \quad (6)$$

- If the additional operational amplifier OP2 is used as a voltage reference or current source, the minimum supply voltage selected ( $V_{CC}$ ) depends on the maximum voltage at pin  $CVREF$ . The following applies:

$$V_{CC} \geq V_{CVREFmax} + 5V \quad (7)$$

When using pin  $V_{OUT}$  and operational amplifier OP2 as a voltage reference or current source the higher value of  $V_{CC}$  must be set.

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## Points to note: initial operation of AM401

1. When operating AM401 it is imperative that external stabilization capacitance  $C_1$  (a high-grade ceramic capacitor) is must **always** connected. 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*). The maximum current drawn from the reference must not exceed a value of  $I_{REF} = 10\text{mA}$ .
2. All of the AM401 function blocks not used by the application (e.g. OP2) must be connected up to a defined (and permitted) potential. Unused blocks, such as the additional operational amplifier (see Figure 3), must be configured. The two capacitances  $C_1$  and  $C_2$  must be connected up in any event, even if the reference voltage source is not used.
3. When OP1 is in operation the load resistance at pin  $V_{OUT}$  must be **at least**  $2\text{k}\Omega$ .

The values of external resistors  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  must be selected so that they lie within the permitted range specified in the boundary conditions on.

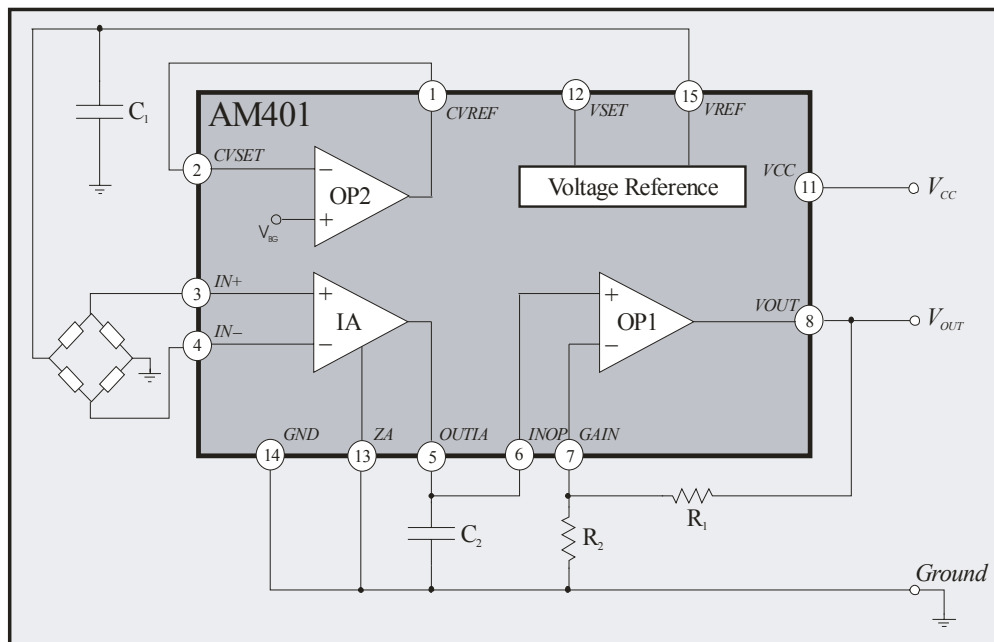


Figure 3: AM401 used as an industrial bridge amplifier

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## APPLICATIONS

### Application 1 – Differential input signal, voltage output signal of 0...5/10V

With applications which require an output voltage of 0...5/10V the pin used to configure the instrumentation amplifier offset (*ZA*) is connected to the IC's *Ground*. Gain *G* is set using the two external resistors *R*<sub>1</sub> and *R*<sub>2</sub>:

$$G = G_{IA} G_{OP} = G_{IA}(1 + R_1/R_2) \quad (2)$$

If no offset voltage is present, the transfer function of the output voltage (Gl.1) is:

$$V_{OUT} = G V_{IN}$$

Using these equations the values of resistors *R*<sub>1</sub> and *R*<sub>2</sub> can be set as follows:

$$\frac{R_1}{R_2} = \frac{V_{OUT}}{G_{IA} V_{IN}} - 1$$

**Example 1:** Input voltage (differential) of 0...50mV and output voltage range of 0...10V

If *V*<sub>IN</sub> = 0...50mV, *R*<sub>1</sub>/*R*<sub>2</sub> = 39 and *I*<sub>REF</sub> ≥ 1mA the values of the external components are as follows:

$$R_1 \approx 117\text{k}\Omega \quad R_2 \approx 3\text{k}\Omega \quad G_{IA} = 5 \quad C_1 = 2.2\mu\text{F} \quad C_2 = 10\text{nF}$$

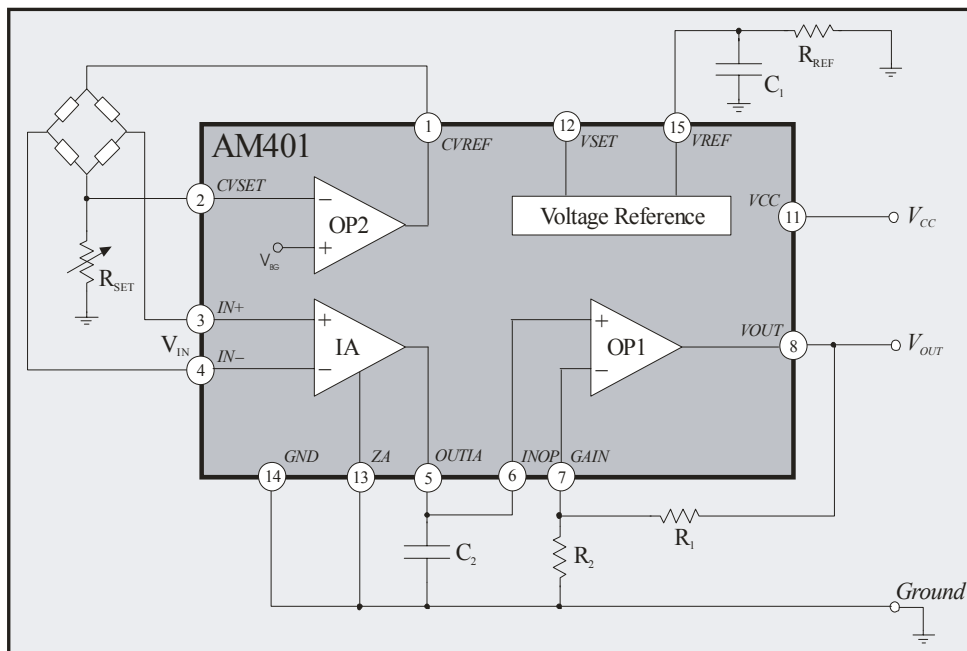
**Example 2:** Input voltage (differential) of 0...100mV and output voltage range of 0...5V

If *V*<sub>IN</sub> = 0...100mV, *R*<sub>1</sub>/*R*<sub>2</sub> = 9 and *I*<sub>REF</sub> ≥ 1mA the values of the external components are as follows:

$$R_1 \approx 90\text{k}\Omega \quad R_2 \approx 10\text{k}\Omega \quad G_{IA} = 5 \quad C_1 = 2.2\mu\text{F} \quad C_2 = 10\text{nF}$$

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## Application 2 – Voltage output signal of 0...5/10V, current-driven sensing element



**Figure 4:** Application for current-driven sensing elements

In this application the additional OP is used as a current source for a resistor measuring bridge. The values of the external components have been calculated for an output voltage of 0...5V; the pin used to configure the instrumentation amplifier offset (ZA) is connected to the IC's Ground. Gain  $G$  is set using the two external resistors  $R_1$  and  $R_2$ :

$$G = G_{IA} G_{OP} = G_{IA} (1 + R_1/R_2) \quad (2)$$

If no offset voltage is present, the transfer function of the output voltage (Gl.1) is:

$$V_{OUT} = G V_{IN} \quad (1)$$

Using these equations the values of resistors  $R_1$  and  $R_2$  can be set as follows:

$$\frac{R_1}{R_2} = \frac{V_{OUT}}{G_{IA} V_{IN}} - 1$$

Supply current  $I_S$  for the sensor bridge can be determined using resistance  $R_{SET}$ :

$$I_S = \frac{V_{BG}}{R_{SET}} \quad (8)$$

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

**Example 3:** Input voltage (differential) of 0...100mV and output voltage range of 0...5V

If  $V_{IN} = 0...100\text{mV}$ ,  $R_1/R_2 = 9$ ,  $I_S = 1.5\text{mA}$ ,  $V_{BG} = 1.27\text{V}$  and  $I_{REF} = 1\text{mA}$  the values of the external components are as follows:

$$\begin{array}{lllll} R_1 \approx 90\text{k}\Omega & R_2 \approx 10\text{k}\Omega & G_{IA} = 5 & C_1 = 2.2\mu\text{F} & C_2 = 10\text{nF} \\ R_{SET} \approx 846.7\Omega & R_{REF} \approx 5\text{k}\Omega & & & \end{array}$$

### Application 3 – Differential input signal, voltage output signal of 0.5...4.5V

With applications which require an output voltage of 0.5...4.5V the pin used to configure the instrumentation amplifier offset ( $Z_A$ ) is connected to voltage  $V_{OFFSET}$  (Figure 5). Gain  $G$  is set using the two external resistors  $R_1$  and  $R_2$ :

$$G = G_{IA} G_{OP} = G_{IA} (1 + R_1/R_2) \quad (2)$$

The transfer function of output voltage  $V_{OUT}$  is:

$$V_{OUT} = G V_{IN} + V_{OFFSET} \quad (1)$$

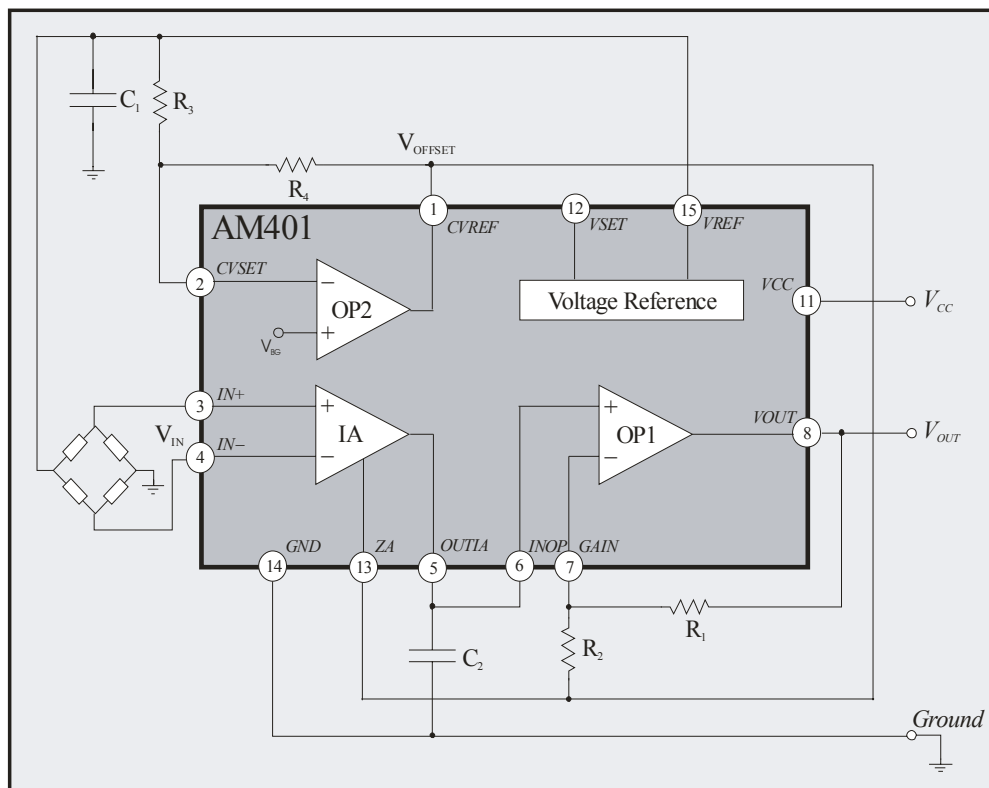
The offset voltage (Equation 3) is calculated as:

$$V_{OFFSET} = V_{BG} - \frac{R_4}{R_3} (V_{REF} - V_{BG}) \Rightarrow \frac{R_3}{R_4} = \frac{V_{REF} - V_{BG}}{V_{BG} - V_{OFFSET}}$$

Using these equations the values of resistors  $R_1$  and  $R_2$  can be set as follows:

$$\frac{R_1}{R_2} = \frac{V_{OUT} - V_{OFFSET}}{G_{IA} V_{IN}} - 1$$

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401



**Figure 5:** Application as a bridge amplifier for an output voltage of 0.5...4.5V

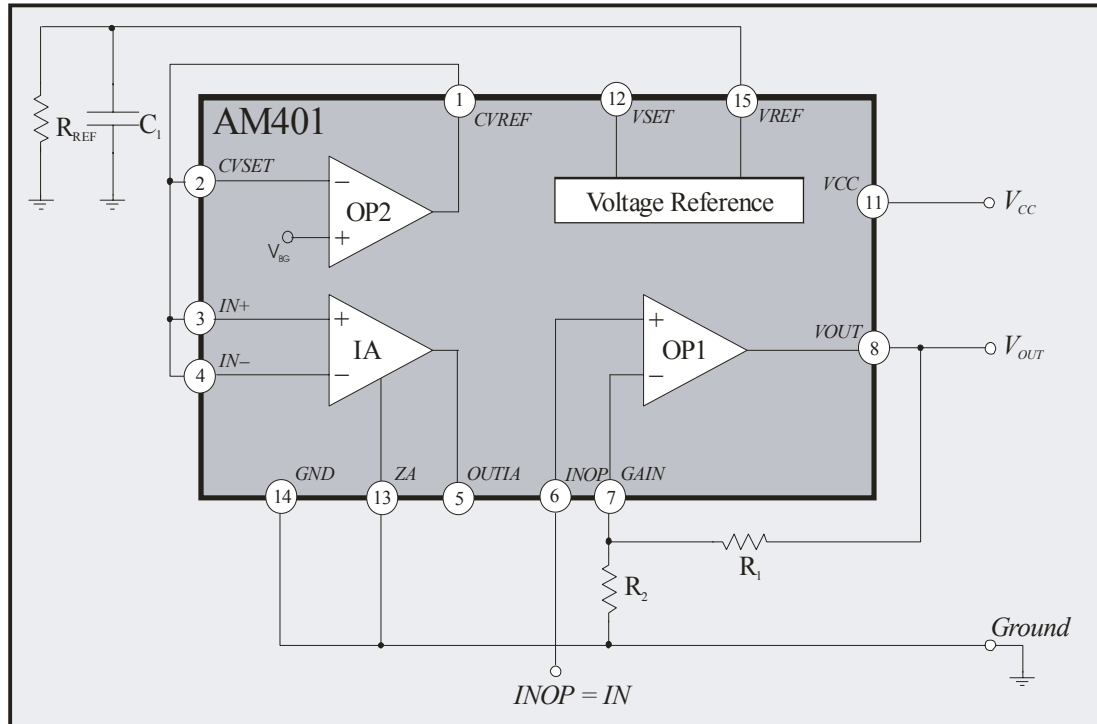
**Example 4:** Input voltage (differential) of 0...250mV and output voltage range of 0.5...4.5V

If  $V_{IN} = 0...250\text{mV}$ ,  $I_{REF} \geq 1\text{mA}$ ,  $R_1/R_2 = 2.2$  and  $R_3/R_4 = 4.8$  the values of the external components are as follows:

$R_1 \approx 100\text{k}\Omega$	$R_2 \approx 47\text{k}\Omega$	$R_3 \approx 75\text{k}\Omega$	$R_4 \approx 15.5\text{k}\Omega$
$V_{OFFSET} = 0.5\text{V}$	$C_1 = 2.2\mu\text{F}$	$C_2 = 10\text{nF}$	

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

**Application 4 – Input voltage (referenced to ground) of 0...1V and output voltage of 0...10V**



**Figure 6:** AM401 with an OP input stage

For a signal of  $V_{IN} = 0...1V$  at the OP1 input the external components are to be dimensioned in such a way that there is an output voltage range of  $V_{OUT} = 0...10V$ . Using the values in Equation 4 the settable gain has a value of:

$$G_{OP1} = \frac{V_{OUT\max}}{V_{IN\max}} = \frac{10V}{1V} = 10$$

where  $V_{IN}$  is the voltage at OP1 input pin  $INOP$ .

According to Equation 5 the below value is calculated for the resistance ratio of the adjustment resistors:

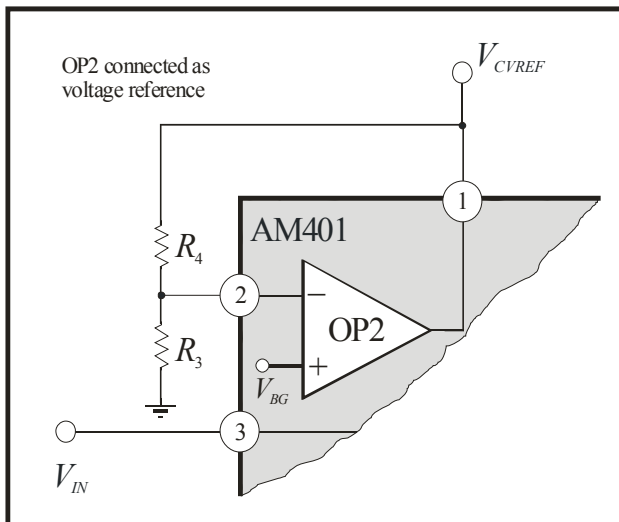
$$\frac{R_1}{R_2} = G_{OP1} - 1 = 9$$

With reference to the boundary conditions for external components given on page 6 the following values are obtained:

$$R_1 \approx 90k\Omega \quad R_2 = 10k\Omega \quad R_{REF} = 5k\Omega \quad C_1 = 2.2\mu F$$

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## Application 5 – Connecting up OP2 as a voltage reference



**Figure 7:** AM401's OP2 as a voltage reference

In addition to the integrated voltage reference of the AM401, the OP2 can also be used as a voltage supply for external components, such as A/D converters or microprocessors, for example. Lower voltages can be generated (e.g. 3.3V) which with the increasing miniaturisation of devices and need for ever lower levels of power dissipation in digital components is today of growing importance.

If in addition to the 5/10V reference a further voltage source is required to power external components the second operational amplifier OP2 can be used to this end.

This operational amplifier can be easily configured as a voltage reference. Using the circuit in Figure 7 the following equation is given:

$$V_{CVREF} = V_{BG} \left( 1 + \frac{R_4}{R_3} \right) = 1.27 \text{ V} \left( 1 + \frac{R_4}{R_3} \right) \quad (9)$$

A voltage of  $V_{CVREF} = 3.3\text{V}$  is to be set. With reference to Equation 9 the following ratio is obtained for the external resistors  $R_3$  and  $R_4$ :

$$\frac{R_4}{R_3} = \frac{V_{CVREF}}{V_{BG}} - 1 \approx 2.6 - 1 = 1.6$$

With reference to the boundary conditions for external components given on page 6 the following values are obtained for the resistors:

$$R_3 = 10\text{k}\Omega \quad R_4 = 16\text{k}\Omega$$



# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

## CIRCUIT TOPOLOGY

### Topology of the 0...5/10V application

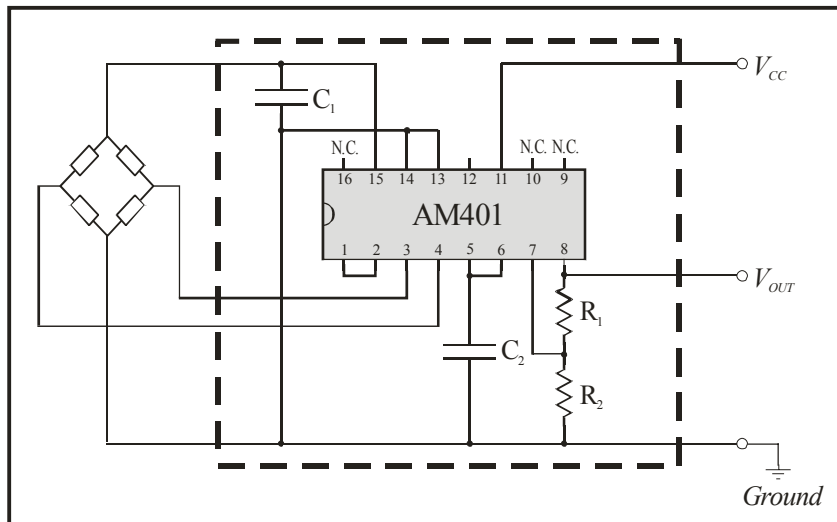


Figure 8: Circuit topology of a 0...5/10V output

### Topology of the 0.5...4.5V application

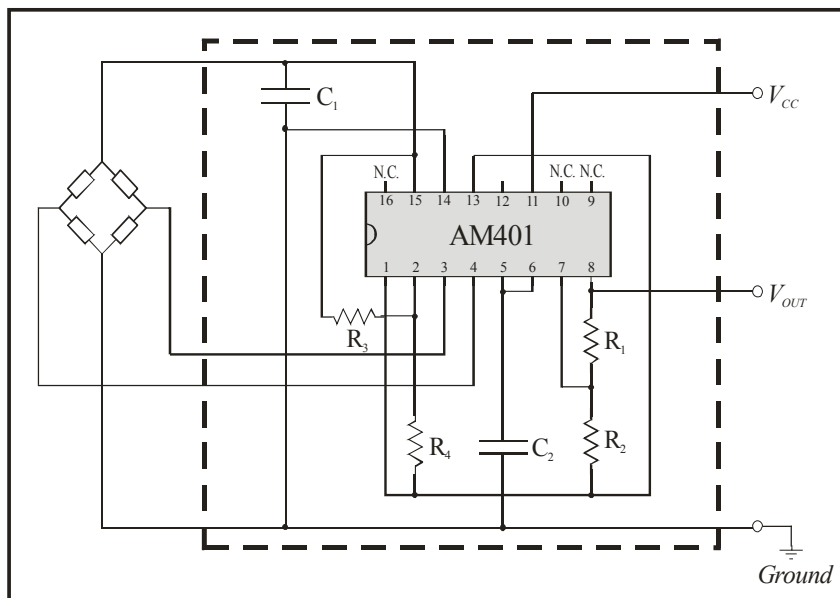
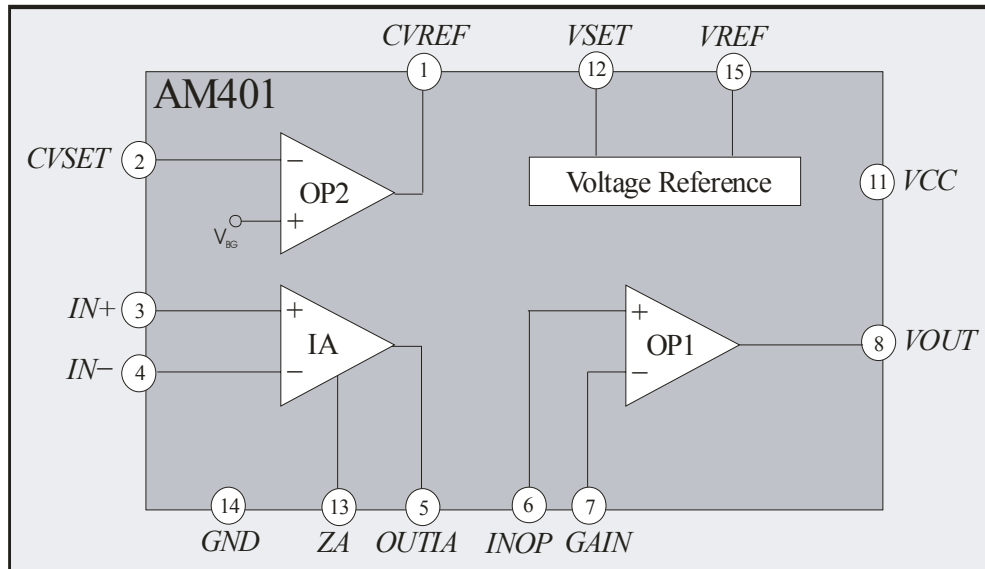


Figure 9: Circuit topology of a 0.5...4.5V output

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

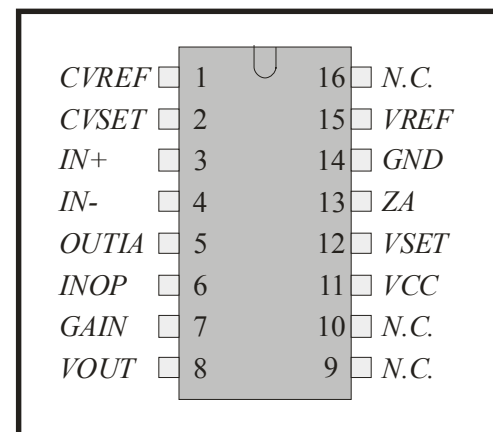
## BLOCK DIAGRAM AND PINOUT



**Figure 10:** Block diagram of AM401 (individually configurable function modules)

PIN	NAME	DESIGNATION
1	<i>CVREF</i>	Current/Voltage Reference
2	<i>CVSET</i>	Current/Voltage Reference Set
3	<i>IN+</i>	Positive Input
4	<i>IN-</i>	Negative Input
5	<i>OUTIA</i>	Instrumentation Amplifier Output
6	<i>INOP</i>	Operational Amplifier Input
7	<i>GAIN</i>	Gain Adjustment
8	<i>VOUT</i>	Voltage Output
9	<i>N.C.</i>	Not Connected
10	<i>N.C.</i>	Not Connected
11	<i>VCC</i>	Supply Voltage
12	<i>VSET</i>	Voltage Select
13	<i>ZA</i>	Zero Adjustment (Offset)
14	<i>GND</i>	IC Ground
15	<i>VREF</i>	Reference Voltage
16	<i>N.C.</i>	Not Connected

**Table 1:** Pin out

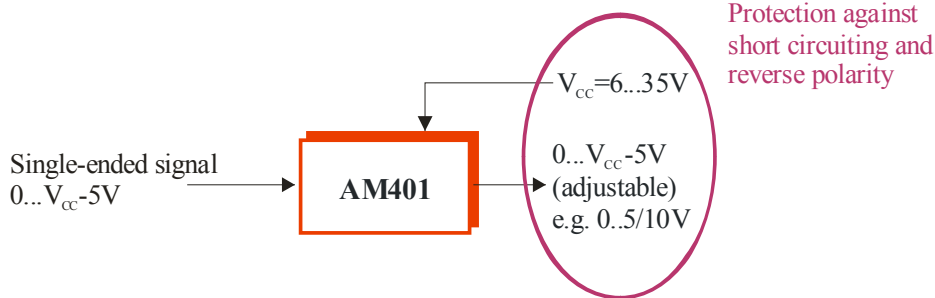


**Figure 11:** AM401 Pin out

# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

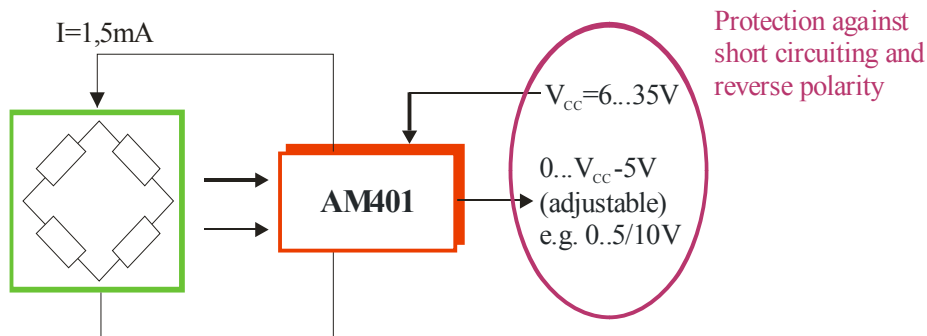
## EXAMPLE APPLICATIONS

- *Application as a voltage converter [3]*



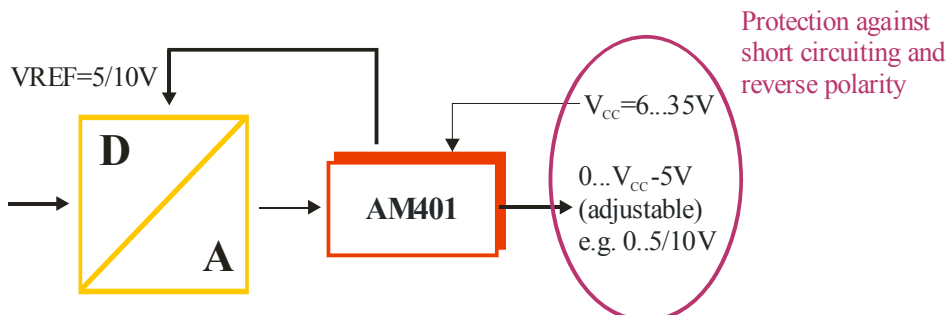
**Figure 12:** Application as a voltage converter for signals referenced to ground

- *Application as an amplifier IC and impedance converter*



**Figure 13:** Application as an amplifier IC and impedance converter for differential signals

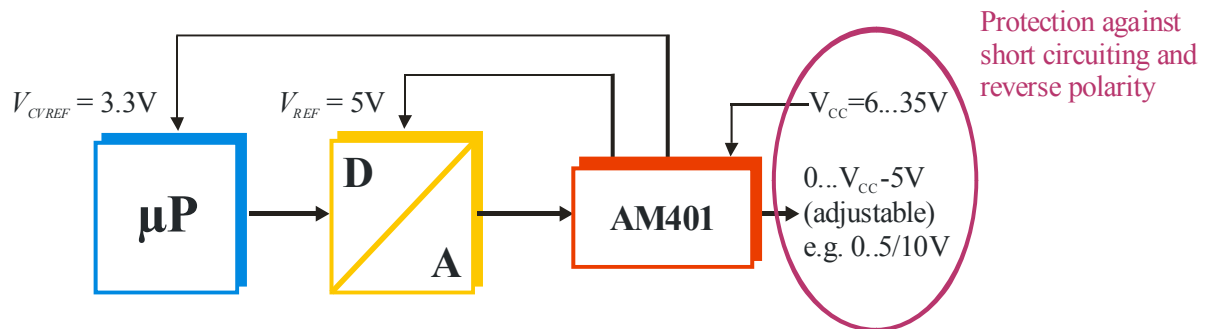
- *Application as a processor interface*



**Figure 14:** Application as a processor interface

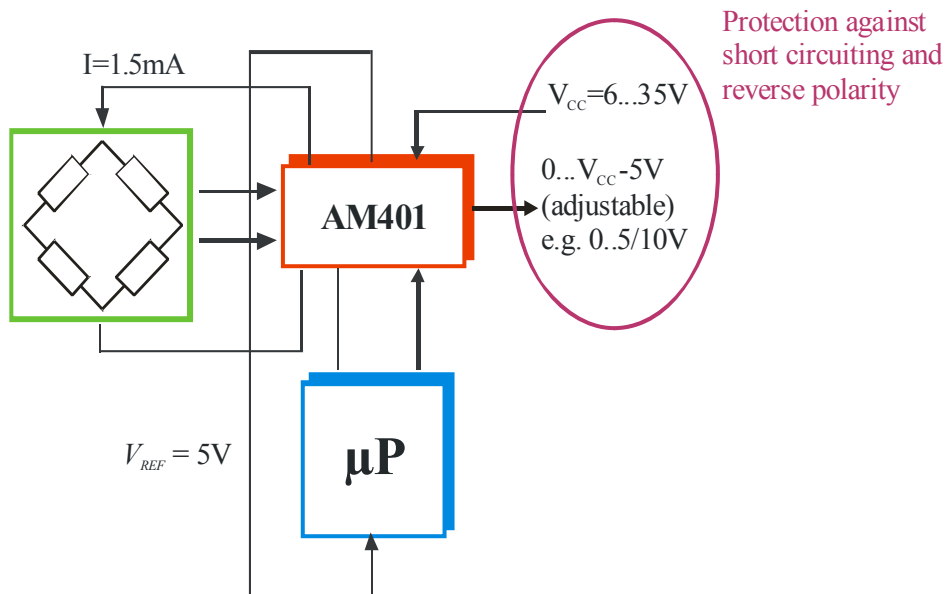
# INDUSTRIAL VOLTAGE AMPLIFIER IC AM401

- *Application as a processor periphery IC*



**Figure 15:** Application as a processor periphery IC

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



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

# INDUSTRIAL VOLTAGE AMPLIFIER IC

## AM401

### DELIVERY

AM401 is available as the following packages:

- 16-pin DIL (samples, small series)
- SO 16 (n): please see our website (data sheets: package.pdf)
- SSOP 16: please see our website (data sheets: package.pdf)
- Dice on 5" blue foil (on request)

### PACKAGE DIMENSIONS

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

### FURTHER READING

- [1] The Frame ASIC concept: <http://www.Frame-ASIC.de/>
- [2] The Analog Microelectronics GmbH website: <http://www.analogmicro.de/>
- [3] Available also for the AM401: Application notes AN1013 on the Analog Microelectronics website: <http://www.analogmicro.de/>

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