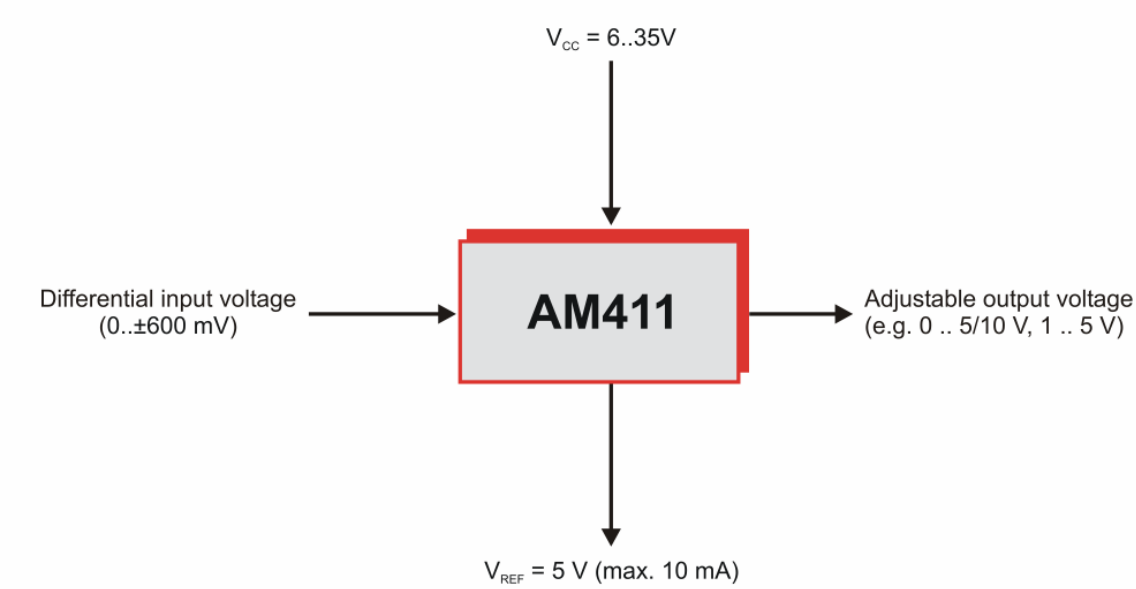
AM411
Low-Cost Voltage Transmitter IC

Principle Function

Industrial amplifier / transmitter IC for differential input voltages with integrated voltage reference and protection functions



Typical Applications

- Universal voltage-transmitter with adjustable gain and offset
- Analog interface IC for differential input voltage signals
- Protected output stage for industrial applications (e.g. 0 .. 10 V)
- Interface and protection IC for microcontrollers
- Non-ratiometric sensor transmitter IC

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FEATURES

- **supply voltage range: 6 .. 35 V**
- **operating temperature range: -40 °C .. +85 °C**
- **voltage reference: 5 V (max. 10 mA)**
- **differential input voltage range: V_{IN} = 0 .. ±600 mV**
- **large common-mode input range: 1.5 .. 6.0 V**
- **output voltage up to 13 V**
- **adjustable gain and offset**
- **several integrated protection functions:**
  - **reverse polarity protection**
  - **protection against permutation of V_{CC}, V_{OUT}, GND**
  - **output current limitation**
  - **short circuit protection**
- **ESD protection**
- **REACH and RoHS conform**

GENERAL DESCRIPTION

AM411 is a universal voltage amplifier / transmitter IC for signal-conditioning applications. It converts a differential input voltage into an amplified, single-ended output voltage. Using this IC standardized industrial output voltage ranges (e.g. 0 .. 5, 0 .. 10 V, 1 .. 5 V) can easily be realized.

The IC consists of an instrumentation amplifier with adjustable offset as input stage and an operational amplifier output stage with adjustable gain. Offset and gain can be set using external resistors. A reference voltage source delivering 5 V with a source current up to 10 mA can be used to power external components (e.g. measurement bridges, microcontrollers).

The IC is internally protected against reverse polarity and permutation of V_{CC}, V_{OUT} and GND. Furthermore it is protected against short circuit of V_{OUT} by an integrated output current limitation.

With its industrial voltage output, protection functions and wide input voltage range AM411 is suitable for a large variety of transducers and sensors.

BLOCK DIAGRAM

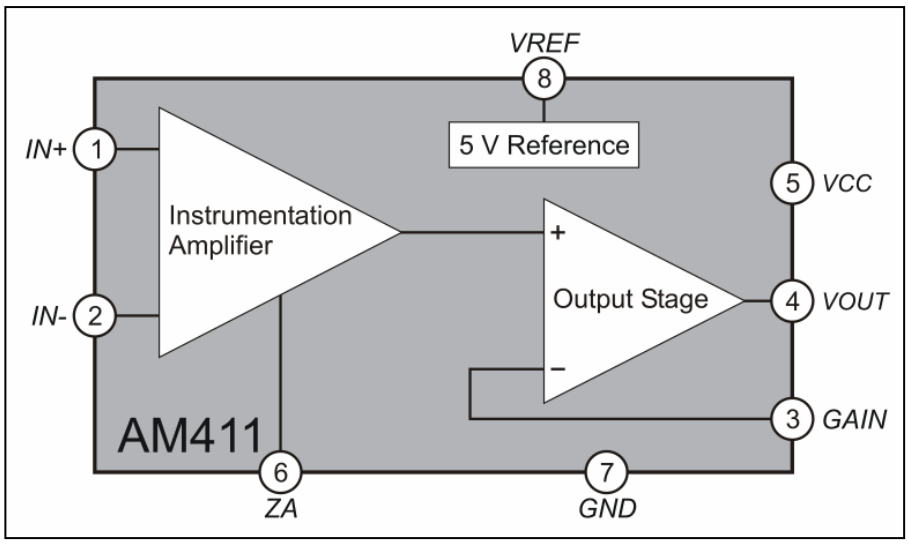


Figure 1: **AM411's block diagram**

SPECIFICATIONS

1. Electric Specifications

T_{amb} = 25°C, V_{CC} = 24 V, V_{REF} = 5 V, I_{REF} = 1 mA (unless otherwise noted)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
System						
Supply Voltage	V_{CC}		6	24	35	V
Quiescent Current	I_{CC}	T_{amb} = -40 .. +85°C, I_{REF} = 0 mA			1.5	mA
Temperature Specifications						
Operating Temperature	T_{amb}		-40		85	°C
Storage	T_{st}		-55		125	°C
Junction	T_J				150	°C
Thermal Resistance	Θ_{ja}	SO8 plastic package		140		°C/W
Voltage Reference						
Voltage	V_{REF}		4.90	5.00	5.10	V
Current	I_{REF}		0		10	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, I_{REF} = 1 mA		30	80	ppm/V
	dV_{REF}/dV	V_{CC} = 6V .. 35V, I_{REF} ≈ 5 mA		60	150	ppm/V
Load Regulation	dV_{REF}/dI	I_{REF} = 1 mA		0.05	0.10	%/mA
	dV_{REF}/dI	I_{REF} ≈ 5 mA		0.06	0.15	%/mA
Load Capacitance	C_L		1.9	2.2	5.0	µF
Instrumentation Amplifier (IA)						
Internal Gain	G_{IA}		4.9	5	5.1	
Differential Input Voltage Range	V_{IN}		0		±600	mV
Common Mode Input Range	$CMIR$	V_{CC} < 9 V, I_{CV} < 2 mA	1.5		V_{CC} - 3	V
	$CMIR$	V_{CC} ≥ 9 V, I_{CV} < 2 mA	1.5		6.0	V
Common Mode Rejection Ratio	$CMRR$		80	90		dB
Power Supply Rejection Ratio	$PSRR$		77	90		dB
Offset Voltage	V_{OS}		-6.0		6.0	mV
V_{OS} vs. Temperatur	dV_{OS}/dT			±5		µV/°C
Input Bias Current	I_B				-300	nA
I_B vs. Temperature	dI_B/dT				-0.9	nA/°C
Zero Adjust Stage						
Internal Gain	G_{ZA}		0.98	1.00	1.02	
Input Voltage ZA	V_{ZA}		0		3	V
Offset Voltage	V_{OS}		-3.0		2.0	mV
V_{OS} vs. Temperature	dV_{OS}/dT			±3	±7	µV/°C
Input Bias Current	I_B				100	nA
I_B vs. Temperature	dI_B/dT				75	pA/°C

Voltage Output Stage						
Adjustable Gain	G_{OP}		1			
Power Supply Rejection Ratio	*PSRR*		80	90		dB
Offset Voltage	V_{OS}		-2		2	mV
V_{OS} vs. Temperature	dV_{OS}/dT			±3	±7	µV/°C
Input Bias Current	I_B			5	12	nA
I_B vs. Temperature	dI_B/dV			3.5	10	pA/°C
Output Voltage Range	V_{OUT}	V_{CC} < 18 V	0		V_{CC} -5	V
	V_{OUT}	V_{CC} ≥ 18 V	0		13	V
Output Current	I_{OUT}		0		$I_{OUT,max}$	mA
Maximum Output Current	$I_{OUT,max}$		5			mA
Load Resistance	R_L		2			kΩ
Protection Functions						
Protection against reverse polarity		*GND vs.* V_{CC}			35	V
Protection against permutation		*GND vs.* V_{CC} *vs.* V_{OUT}			35	V
Short circuit protection of VOUT		V_{OUT} *at GND. /* V_{OUT} *at* $V_{CC,max}$	0		35	V
System Parameters						
Nonlinearity		*Ideal input*		0.03	0.1	% FS

***Table 1: AM411*'s electric specifications**

Notes:

1) Currents flowing into the IC are negative. Muss im Test geändert werden

2. Boundary Conditions

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Sum Gain Resistors	$R_1 + R_2$	*for* $G_{OP} \neq 1$	20		200	kΩ
Stabilization Capacitance @ V_{REF}	C_1	*-40 ≤* T_{amb} *≤ 85°C*	1.9	2.2	5.0	µF

***Table 2:* Boundary Conditions**

APPLICATION INFORMATION

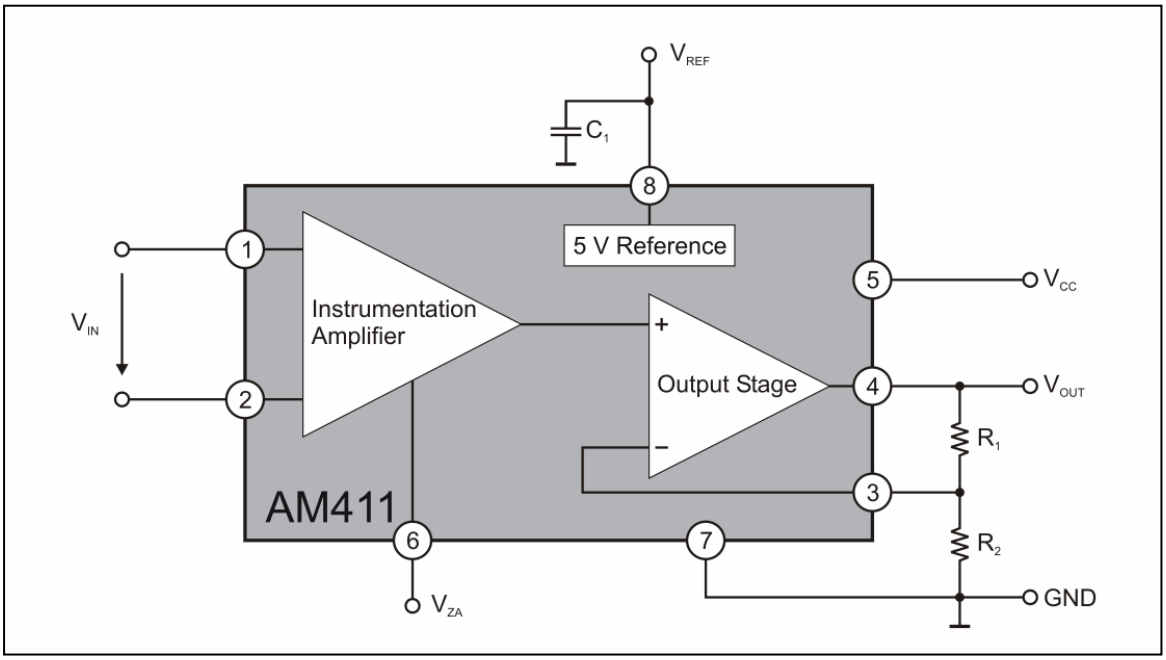
1. Functional Principle

AM411 is an integrated voltage amplifier / transmitter, which can be used for the signal-conditioning of differential voltage input signals. As shown in *Figure 2* AM411 basically consists of three functional blocks:

1. An instrumentation amplifier with an internal gain of $G_{IA} = 5$ as input stage for a differential voltage input signal. Using pin ZA the instrumentation amplifier's offset voltage can be adjusted / increased to accept negative differential voltage input signals.[1]
2. An operational amplifier as output stage, whose gain can be adjusted using two external resistors R_1 and R_2.
3. A voltage reference generating a stable 5 V output, which is able to source up to 10 mA and can be used to power external devices like microprocessors or sensors. It is essential to stabilize the reference voltage with an external ceramic capacitor C_1. This capacitor has to be connected even if the voltage reference is not used.

Furthermore AM411 has a multitude of integrated protection functions, which satisfy industrial needs:

- AM411 is protected against reverse polarity (pin VCC at *GND* and pin GND at V_{CC})
- AM411's output is protected against short circuit (pin VOUT at *GND* or pin VOUT at V_{CC}) by an integrated current limitation.
- The pins VOUT, VCC and GND are protected against permutation across the entire supply voltage range without the need for any additional external components.
- Except for the pins VOUT, VCC and GND all pins are protected by internal ESD diodes.



[1] The pin ZA has to be connected to *GND* or to a voltage within V_{ZA}'s input range at all times.

2. Transfer Function

AM411's transfer function is given by:

$$V_{OUT} = G_{OP} \cdot (G_{IA} \cdot V_{IN} + V_{ZA}) \qquad \text{with} \qquad G_{OP} = 1 + \frac{R_1}{R_2} \tag{1}$$

with

V_{OUT} = output voltage
V_{IN} = differential input voltage
V_{ZA} = voltage at pin ZA
G_{IA} = the instrumentation amplifier's internal gain (G_{IA} = 5)
G_{OP} = the output stage's gain set by R_1 and R_2
R_1, R_2 = external resistors used to adjust G_{OP} (see *Figure 2)*

3. Choosing the supply voltage

In principle AM411 can be used in the complete specified supply voltage range (V_{CC} = *6 .. 35 V*), but it has to be noted that for small supply voltages $V_{CC} \leq 18\ V$ the possible maximum output voltage $V_{OUT,MAX}$ is given by[2]:

$$V_{OUT,MAX} = V_{CC} - 5\ V \tag{2}$$

Figure 2: AM411 with necessary external components

For example a supply voltage of $V_{CC} = 10\ V$ limits the possible maximum output voltage to $V_{OUT,MAX} = 5\ V$.

4. Adjusting the system's gain and offset

As can be seen from equation (1) AM411's gain can be adjusted using the external resistors R_1 and R_2 and a positive offset can be set using pin ZA[3].

R_1 and R_2 can be calculated for a given system with a desired maximum and minimum output voltage as well as a given maximum and minimum differential input voltage using the following equation:

$$\frac{R_1}{R_2} = \frac{V_{OUT,\max} - V_{OUT,\min}}{5 \cdot (V_{IN,\max} - V_{IN,\min})} - 1 \tag{3}$$

with

$V_{IN,min}$ = minimum differential input voltage
$V_{IN,max}$ = maximum differential input voltage
$V_{OUT,min}$ = minimum output voltage
$V_{OUT,max}$ = maximum output voltage

Using $V_{OUT,min}$ the required voltage at pin ZA can be determined using equations (1) and (3)

$$V_{ZA} = \frac{5 \cdot (V_{IN,\max} - V_{IN,\min})}{V_{OUT,\max} - V_{OUT,\min}} \cdot V_{OUT,\min} - 5 \cdot V_{IN,\min} \tag{4}$$

Please note, that for a positive differential input voltage signal, $V_{IN} \geq 0$, a mimum output voltage $V_{OUT,min} = 0\ V$ can only be achieved if the minimum input voltage $V_{IN,min} = 0\ V$ and pin ZA is connected to *GND*. For a negative differential or bidirectional differential input voltage signals with $V_{IN,min} < 0$, a voltage $V_{ZA} \geq 5 \cdot V_{IN,min}$ at pin ZA is necessary for operation. Furthermore the boundary conditions in *Table 2* have to be respected during the dimensioning of R_1 and R_2.

[2] For supply voltages $V_{CC} > 18\ V$ the maximum output voltage $V_{OUT,max}$ cannot be larger than 13 V.
[3] Please note, that only a positive offset can be set using pin ZA.

Example 1: Desired output voltage range 0 .. 5 V, input voltage range 0 .. 200 mV

In the following example a differential input voltage range of V_{IN} = *0 .. 200 mV* has to be amplified to an output voltage range of *0 .. 5 V*. Because of the desired maximum output voltage $V_{OUT,max}$ = *5 V* a minimum supply voltage of $V_{CC,min}$ = *10 V* is needed. The dimensioning of the resistors R_1 and R_2 can be done using equation (3).

With $V_{IN,min}$ = *0 V*, $V_{IN,max}$ = *200 mV*, $V_{OUT,min}$ = *0 V* and $V_{OUT,max}$ = *5 V* the following relation can be obtained from equation (3):

$$R_1 = 4 \cdot R_2$$

Together with the boundary conditions given in *Table 2* the following dimensioning of the external components can be obtained:

R_1 = *100 kΩ* R_2 = *25 kΩ* C_1 = *2.2 µF*

Example 2: Desired output voltage range 1 .. 5 V, input voltage range 0 .. 160 mV

The circuit shown in *Figure 3* can be used, if the system's offset and gain have to be adjusted. To generate V_{ZA} AM411's voltage reference is used in combination with a voltage divider consisting of R_3 and R_4.

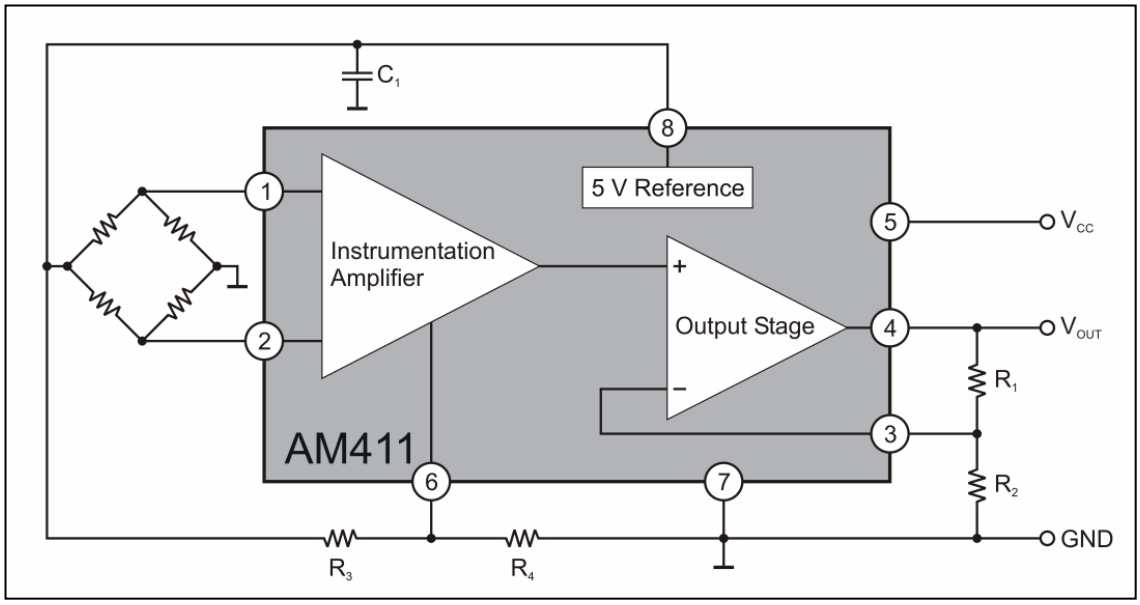


***Figure 3:* AM411's external circuit for offset and gain adjustment**

Using equation (3) as well as $V_{IN,min}$ = *0 V*, $V_{IN,max}$ = *160 mV*, $V_{OUT,min}$ = *1 V* and $V_{OUT,max}$ = *5 V* the following relation can be obtained for R_1 and R_2:

$$R_1 = 4 \cdot R_2$$

and with equation (4) the voltage at pin ZA can be calculated to V_{ZA} = *200 mV*.

Since V_{ZA} is adjusted using R_3 and R_4 and V_{REF} = *5 V* the following relation can be obtained:

$$\frac{R_3}{R_4} = \frac{5V}{V_{ZA}} - 1 \qquad (5)$$

With V_{ZA} = *200 mV* this leads to R_3 = *24* · R_4.

With I_{REF} = *0.2 mA* and the boundary conditions for R_1 and R_2 given in *Table 2* the following dimensioning of the external components can be obtained:

R_1 = *100 kΩ* R_2 = *25 kΩ* R_3 = *24 kΩ* R_4 = *1 kΩ* C_1 = *2.2 µF*

Example 3: Desired output voltage range 0 .. 10 V, input voltage range -100 .. 100 mV

In this example a differential input voltage range of V_{IN} = *-100 mV .. 100 mV* will be amplified and offset adjusted to an output voltage range of V_{OUT} = *0 .. 10 V* using the circuit shown in *Figure 3.*

With $V_{IN,min}$ = *-100 mV*, $V_{IN,max}$ = *100 mV*, $V_{OUT,min}$ = *0 V* and $V_{OUT,max}$ = *10 V* and equation (3) the following relation can be obtained for R_1 and R_2:

$$R_1 = 9 \cdot R_2$$

and with equation (4) the voltage at pin ZA can be calculated to V_{ZA} = 500 mV. Using equation (5) this leads to:

$$R_3 = 9 \cdot R_4$$

With I_{REF} = *0.16 mA* (< *10 mA*) and the boundary conditions for R_1 and R_2 given in *Table 2* the following dimensioning of the external components can be obtained:

R_1 = *27 kΩ* R_2 = *3 kΩ* R_3 = *27 kΩ* R_4 = *3 kΩ* C_1 = *2.2 µF*

5. Operation Instructions

The following points have to be considered while working with AM411:

1. A high quality ceramic capacitor has to be connected at pin VREF, even if the reference voltage source is not used. If AM411 is exposed to large temperature changes, special care must be taken that this capacitor's value stays inside the specified range (see *Table 2*).
2. The external resistors R_1 and R_2, which are used for gain adjustment, have to fullfill the boundary condition $R_1 + R_2$ = *20 .. 200 kΩ*.
3. Under normal operating conditions components powered using the voltage reference (pin VREF) may not drain more than 10 mA.
4. Generally only positive voltage offsets can be generated if a voltage is applied at pin ZA. If Pin ZA is not used it has to be connected to *GND*.
5. In general for positive differential input voltage signals, $V_{IN} \geq 0$, a mimum output voltage $V_{OUT,min}$ = *0 V* can only be achieved if the minimum input voltage $V_{IN,min}$ = *0 V* and V_{ZA} = *0 V*.
6. For negative differential or bidirectional diffferential input voltage signals with $V_{IN,min} < 0$, a voltage $V_{ZA} \geq 5 \cdot V_{IN,min}$ is necessary for operation of AM411.
7. AM411's output short circuit protection is realized by a continous current limitation of the output. The minimal threshold for the current limitation is 5 mA, leading to a thermal power deposition of 180 mW (at V_{CC} = *36 V*), when no further components are powered by the IC.
8. AM411 is protected against reverse polarity and permutation of VOUT, VCC and GND. Please take care that components powered by V_{REF} have to be protected seperately in case of reverse polarity or permutation of V_{CC} versus *GND*.

In general ESD precautions are necessary during assembly and handling of the device. It is essential to ground machines and personnel properly.

PACKAGE AND PINOUT

The AM411's standard packaging is a SO8 package (for dimensions please see the packaging catalog http://www.analogmicro.de/products/analogmicro.de.en.package.pdf).

PIN	NAME	BESCHREIBUNG
1	*IN+*	Non-inverting instrumentation amplifier input
2	*IN-*	Inverting instrumentation amplifier input
3	*GAIN*	Gain adjustment
4	*VOUT*	Voltage output
5	*VCC*	Supply voltage
6	*ZA*	Zero adjust
7	*GND*	IC Ground
8	*VREF*	Reference voltage

Table 3: **Pin assignment AM411 SO8 Package**

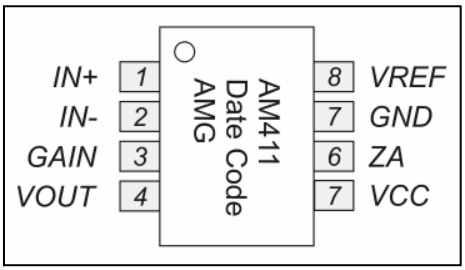


Figure 4: **Pinout AM402 SO8**

DELIVERY FORMS

AM411 is available as:

ORDER NUMBER	DELIVERY FORM
AM411-0-SO8	AM411 in an SO8(n) package
AM411-WAF	sawn 6" wafer on blue foil
AM411-Adapt	AM411 soldered to an SO8-DIL8 adapter

FURTHER LITERATURE

1. Package catalog (see www.analogmicro.de)
2. AM411 – Die Size and Padout (on request)
3. AM411 Application Notes (see www.analogmicro.de)

NOTES