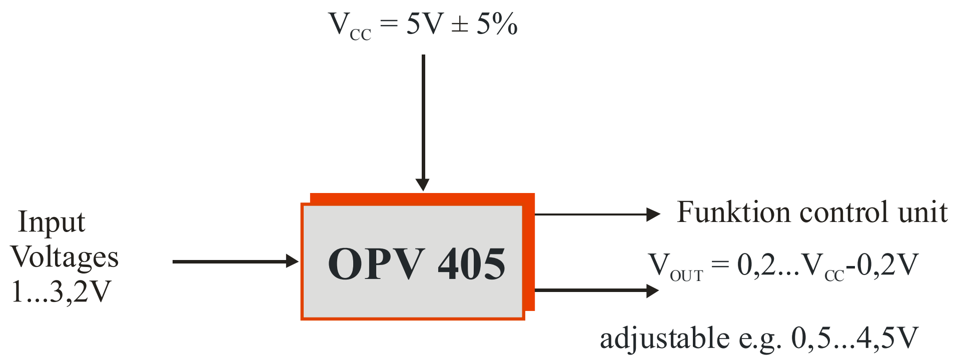
OPV405 – Precision operational amplifier with integrated error detection functions

PRINCIPLE FUNCTION

Precision operational amplifier for input signals of 1 to 3.2V with a control function for the monitoring of operating parameters and internal OPAmp functions



TYPICAL APPLICATIONS

In principle all applications in which precision operational amplifiers are used as an inverting and non-inverting amplifier or differential amplifier etc. are typical here. OPV405 is distinguished by its multifunctional control unit which makes the IC suitable for use in decentralized error detection in electrical machines and apparatus.

- Precision amplifier circuits with a rail-to-rail output
- Amplifier circuits with performance parameter monitoring
- Measuring amplifiers for sensors with system monitoring
- Adjustable current monitoring
- Adjustable current sources with load current monitoring

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Phone: +49 (0)6131/91 0730-0
Fax: +49 (0)6131/91 073-30
Internet: http://www.analogmicro.de
Email: info@analogmicro.de

Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz

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FEATURES

- Low offset voltage
- Low offset voltage drift
- Low input noise
- High CMRR: typ. > 120dB
- Wide operating temperature range: T = -45°C ... +125°C
- Rail-to-rail output stage: V_{OUT} = 0.2V ... V_{CC} -0.2V
- Sink/Source competent
- Integrated temperature detector
- Integrated control functions
- Integrated protective EMC functions
- Modular functions
- Short-circuit protection
- Small design
- RoHS compliant

GENERAL DESCRIPTION

OPV405 functions as an operational amplifier. Besides this feature it also has an effective and comprehensive control unit so that a self-monitoring amplifier circuit can be assembled using very few components.

A multistage, high precision, low noise amplifier circuit with a low offset and low offset drift makes up the core of this IC. The OPV405 has a rail-to-rail output and an internal short-circuit protection unit. It can be used across a wide temperature range.

An integrated function control unit monitors the amplifier and several performance parameters. This indicates disturbances at the amplifier inputs, supply undervoltage, OP output stage overloads and also excessive temperature in the IC, displaying this information at a status output.

OPV405 has the pinout of a standard dual OP and can be operated with an asymmetrical supply voltage of 0 and 5V or a symmetrical supply of -2.5V and +2.5V.

BLOCK DIAGRAM

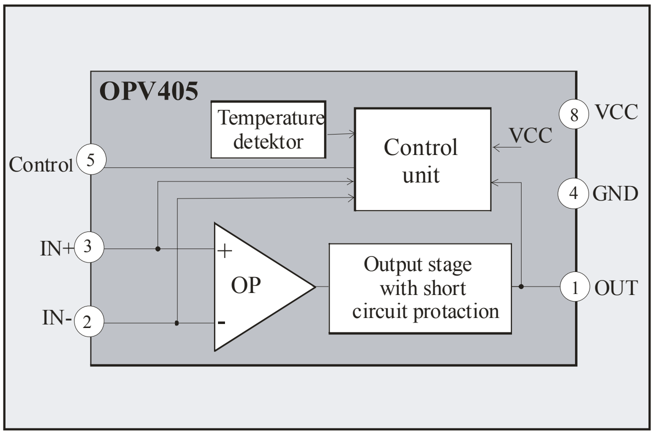

Figure 1: **Block diagram of OPV405**

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ELECTRICAL SPECIFICATIONS

T_{amb} = 25°C, V_{CC} = 5V (unless otherwise stated)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{CC}		4.5	5	5.5	V
Quiescent Current	I_{CC}	T_{amb} = - 45...+125°C		1.45	2.35	mA
Temperature Specification*						
Operating	T_{amb}		-45		125	°C
Storage	T_{st}		-55		150	°C
Junction	T_J				150	°C
Operational Amplifier (OP)						
Offset Voltage	V_O			±0.1	±0.3	mV
V_{OS} vs. Temperature	dV_O/dT	T_{amb}= *-45…105°C*		±0.5	±3	µV/°C
		T_{amb}= *105…125°C*			±6	µV/°C
Input Bias Current	I_B	*Common mode voltage* V_{CM} = 2.5V		30	200	nA
I_B vs. Temperature	dI_B/dT	T_{amb}= *-45…125°C*		-0.13	-0.6	nA/°C
Input Offset Current	I_O	V_{CM} = 2.5V		±0.5	±5	nA
I_O vs. Temperature	dI_{OS}/dT	T_{amb}= *-45…125°C*		±2.5	±30	pA/°C
Input Resistance	R_{IN}	V_{CM} / $I_{B,typ}$ (V_{CM} = 2.5V)		80		MΩ
Input Capacitance	C_{IN}			90		pF
Input Voltage Range	V_{IN}		1		3.2	V
Common Mode Rejection Ratio	*CMRR*		100	120		dB
Open Loop Gain	G_0	*C1* = 1nF; *Iout* = 1µA	120	140		dB
Adjustable Gain	*G*		10			
Min. Output Voltage	V_{Outmin}			0.2		V
Max. Output Voltage	V_{Outmax}			*VCC* -0.2		
Maximum Output Current	I_{OUT}	Sink and source	250			µA
Power Supply Rejection Ratio	*PSRR*		90	110		dB
Unity Gain Bandwidth	*UGB*	R1,2 = 1k Rk = 10k, *C1* = 1nF, *Ck* = 100pF, no RL	190	310		kHz
Slew Rate	*SR*	*C1* = 1nF; *Iout* = 250µA	0.2	0.3		V/µs
Input Voltage Noise	e_n	T_{amb} = 25°C, *Rs* = 100Ω, V_{CC} = 5V, f_g = 1kHz *Rs* = Source Impedance		13.5	20	nV/√Hz

Table 1: **Electrical specifications**

*The thermal resistance pertinent to the package under discussion can be found at: www.analogmicro.de/products/analogmicro.de.en.package.pdf

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Email: info@analogmicro.de

Control Unit Parameter	Symbol	Condition	Min.	Typ	Max.	Unit
Control Output voltage *on Error* (high level)	V_{Contr}			*VCC* -0.2		V
Control Output voltage *without Error* (low level)	V_{Contr}			*GND* +0.2		V
Output Current on Error	I_{ERR}	V_{Contr} = 0.5Vcc	1.5	3.5	6	µA
Output Current without Error	I_{NOERR}	V_{Contr} = 0.5Vcc	-6	-3.5	-1.5	µA
Overtemperature Range	T_{ERR}	See 3	125		143	°C
Output Current Range	$I_{IA,ERR}$	See 3	250		800	µA
Low Supply Voltage Range	$V_{CC,ERR}$	See 4	3.8		4.3	V
High Input Voltage Range	$V_{IN,high,ERR}$	See 3	*VCC* -1.8		*VCC* -0.8	V
Low Input Voltage Range	$V_{IN,low,ERR}$	See 4	0.4		0.8	V

Table 2: S**pecifications of the control function**

Remarks on the specifications:

1. Currents flowing into the IC have a negative sign. With an asymmetrical supply voltage the following applies: *V+ = Vcc* and *V- = GND*.
2. V_{CM} = common mode voltage; when V_{CC} = 5V→V_{CM} = 2.5V and when V_{CC} = ±2.5V→V_{CM} = 0V.
3. Below the minimum threshold of the active range the *Control* output (pin 5) is always at GND +0.2V. Above the maximum threshold of the active range output *Control* is safe at V_{CC} -0.2V.
4. Below the minimum threshold of the active range the *Control* output (pin 5) is always at V_{CC} -0.2V. Above the maximum threshold of the active range output *Control* is safe at GND +0.2V.

DESCRIPTION OF FUNCTIONS

Operational amplifier

OPV405 is distinguished by its low offset voltage and low thermal offset drift across a wide temperature range, classing it as a precision operational amplifier. It is thus suitable for circuits which are critical regarding the offset and which only permit a minor influence of temperature

The operational amplifier OPV405 is a multistage amplifier which is capable of processing input voltages of 1 to 3.2. V. The output is adjustable and his max. value is 0.2V to Vcc -0.2V (rail-to-rail output). He can drive load currents (sink and source) of up to 250µA and is short-circuit-protected. The IC operates with a supply voltage of 5 V ± 5% and has an output ratiometric to the supply voltage.

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Control Unit

Besides its function as an operational amplifier the OPV405 also has an integrated multifunction control unit, enabling disturbances in or deviations from the performance parameters to be signaled. This means that if given values are overshot or undershot, this can be clearly indicated.

This feature does not allow disturbance values to be indicated with any precision; it simply indicates with respect to the deviations from IC production or components tolerances if some internal or external parameters overshoot or undershoot the specified minimum and maximum values (control unit response thresholds). OPV405 can thus be used to monitor both its own main functions and the operating parameters. It therefore makes an ideal decentralized error detector in electrical circuits.

The following errors are indicated:

- One of the two or both operational amplifier inputs > $V_{IN\ MAX}$ = 3.2V (e.g. input is connected to V_{CC})
- One of the two or both operational amplifier inputs < $V_{IN\ MIN}$ = 0.9V (e.g. input is connected to GND)
- One of the two or both inputs are not connected
- The operational amplifier load current is too high (output stage overload I_L > 250µA)
- There is undervoltage (supply voltage Vcc < 4.3V)
- The IC temperature is to high (T > 125°C)
- The output is saturated (Vout < 0.2V or Vout > Vcc -0.2V)

In the event of one or more disturbances the multifunction control output (pin 5) assumes a logic high (V_{CC} -0.2V). If no error is present a logic low (GND +0.2V) is assumed. More details concerning the potential failure causes see [1].

The output status of the control unit can be made visible using an LED and an additional transistor (Darlington transistor, see *Figure 3*).

OPV405's two modular function blocks (the operational amplifier and multifunction control unit) can either be used separately or in conjunction with one another. If only the function control unit is to be used, circuit component OP (see *Figure 1*) must be placed in a defined state within the limits of the specifications.

Phone: +49 (0)6131/91 0730-0
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Internet: http://www.analogmicro.de
Email: info@analogmicro.de

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OPV405 IN AN AMPLIFIER CIRCUITRY

OPV405 functions as an operational amplifier and can be configured as either an inverting or non-inverting amplifier, for example. It must be observed that OPV405 cannot be used as a unity gain bandwith amplifier; see APPLICATIONS!

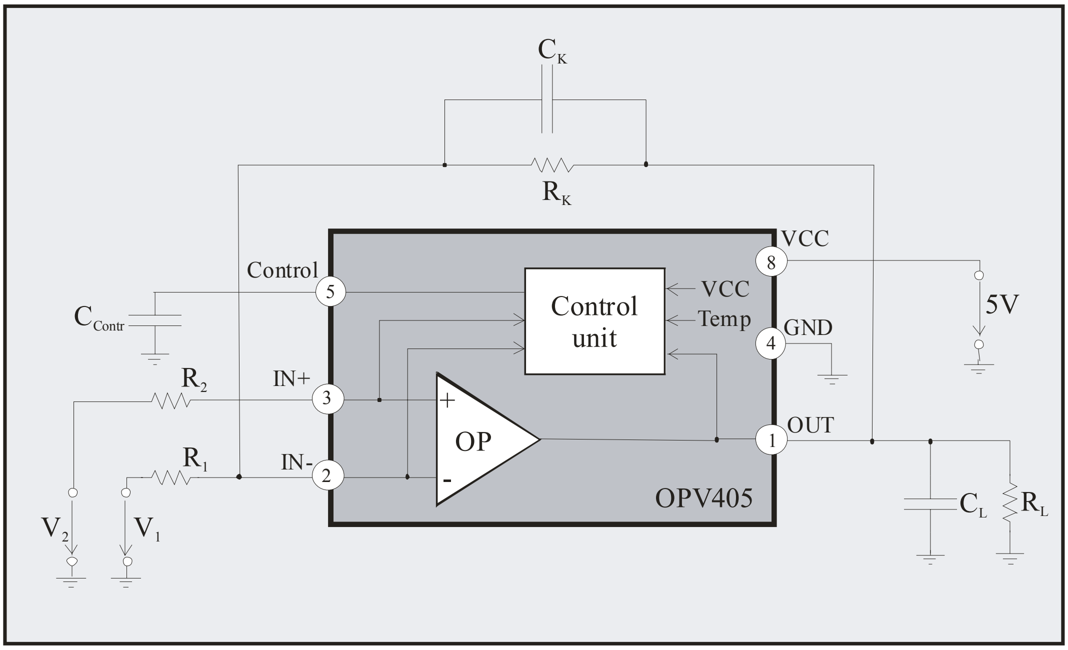

***Figure 2*: OPV405 as an amplifier circuit**

The following external components are required for the stable operation of OPV405:

OP Output Load Capacity	C_L	Essential	1		5	nF
OP Compensation Capacity	C_k	Essential		0.1		nF
Control Out Capacity	C_{contr}	Optional		3.3		nF

***Table 2:* Stabilizing capacitors**

INITIAL OPERATION

Before the device first goes into operation, it should be checked that the essential compensation capacitors C_L and C_K are present.

Input signals V_1 and V_2 must be set to the required potential (V_{CM}) so that the signal deviation lies within the permissible input range of the operational amplifier. Supply voltage Vcc is then connected up to the circuit. For reasons of symmetry (input signal drive), when V_{CC} = 5V it is advisable to select V_{CM} = 2.5V.

As the gain factor of OPV405 must be at least 10 and the output deviation has a maximum of 4.6V, the swing of the input signal may not be greater than ±230mV. When V_{CC} = ±2.5V and V_{CM} = 0V (GND) the input signal range subsequently has a maximum value of V_{IN} = ±230mV. Smaller input signals require higher gain factors depending on the output signal needed.

The amplification of the voltage is set via the selection of R_K and R_L ($R_2 = R_1$); here, it is essential that $G \geq 10$.

The sum of the currents through R_K (feedback) and R_L (load current) must not exceed the maximum current of the output stage (I_{OUT} = 250µA) in any mode of operation. This must be taken into consideration during dimensioning; further details are given in APPLICATIONS.

Conditions: The input signal, amplified by a factor of $g = R_K / R_L$, is transmitted to the output. The operational amplifier can drive a load resistor (R_L) at the output. The sum of the currents through R_K and R_L must not exceed the maximum load current of 250µA.

The following factors must be observed here; the input voltage range is expressed by

$$1V \leq (V_{IN-}, V_{IN+}) \geq 3.2V$$

and the minimum gain of the operational amplifier by

$$|g_{\min}| = \frac{R_k}{R_1} \geq 10 .$$

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APPLICATIONS

Example application 1: OPV405 as an inverting amplifier with error indication

In this application the control output is to drive an LED with the help of a transistor and optically display an error.

The input signal of a signal source, such as a sensor, and important performance parameters in a sensor system (sensing element plus signal conditioning) are to be monitored and an error indicated.

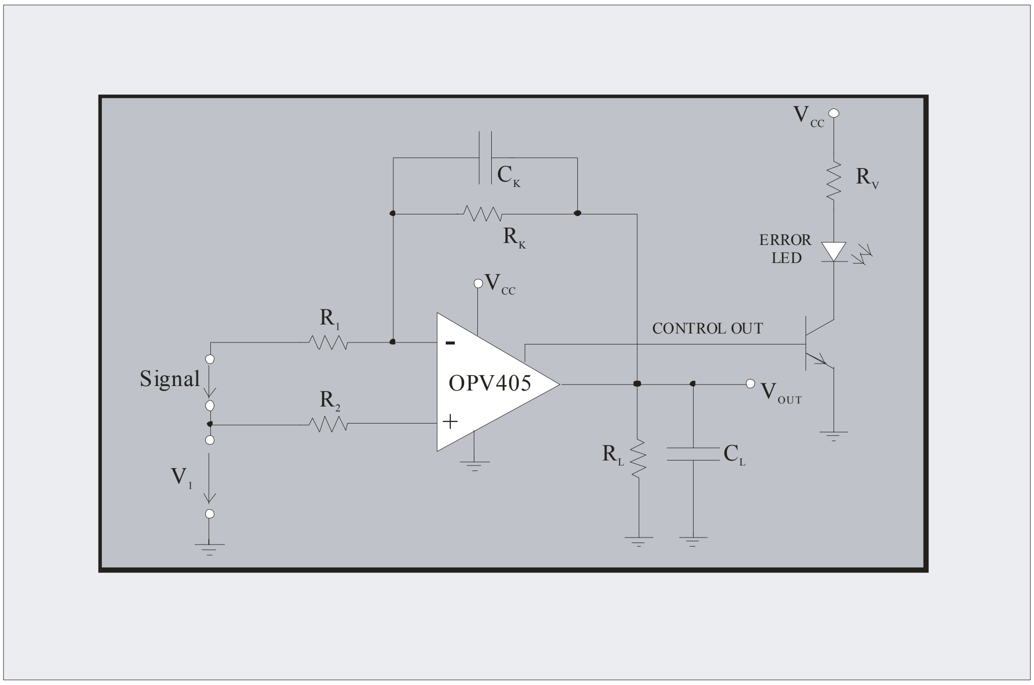

Figure 3: **OPV405 as an inverting amplifier with a monitor function**

Example: V_{IN} = ±100mV, V_{CC}= 5V, Vout = 1..4V and Iout (max) = 250µA

The output of the inverting amplifier should be adjusted symmetrically by $0.5 \cdot Vcc = 2.5$ V. It thus follows that:

$$V_{OUT} = 2.5\text{V} \pm 1.5\text{V}.$$

The required gain is: $g = \frac{1.5V}{100mV} = 15$. As we are dealing with an inverting amplifier here, g = -15.

Input voltage V_1 must be connected to a reference potential of : $2.5V = 0.5 \cdot Vcc$

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When activated the input signal then deviates between 2.5V ± 100mV and is thus always within the input voltage range of OPV405.

For a maximum input value of V_1+V_{IN} = 2.5 +100mV, output value V_{OUT} = 1V; for a minimum input value of V_1-V_{IN} = 2.5 - 100mV, output value V_{OUT} = 4V.

The equation used to calculate the gain is: $g = -\frac{R_K}{R_1}$

R_K must thus be 15 times greater than R_L. Where possible R_K is selected with a high impedance so that there is enough residual current to drive a load resistor:

$$I(R_K) + I(R_L) = 250\mu A.$$

One possible value for R_k would be 150kΩ, for example. This results in a value of 10kΩ for R_1 (R_K/15). R_2 is selected so that it equals R_1; this reduces the error caused by the input currents of the OP.

A maximum of $I_{K1} = \frac{(4V - 2.5V)}{150k\Omega}$ or $I_{K2} = \frac{(2.5V - 1V)}{150k\Omega}$ flows through $R_K \rightarrow I_K = 10\mu A$.

The following is still available for the load current:

$$I_L = 250\mu A - 10\mu A = 240\mu A.$$

This generates a minimum value for the load resistor of:

$$R_L \geq \frac{4V}{240\mu A} = 16.6k\Omega.$$

The amplifier output is adjusted to between 1V and 4V by the input signal ±100mV. When V_{OUT} = 1V and V_{OUT} = 4V the permitted maximum current of 250µA then flows through the output stage of the operational amplifier.

The multifunction control unit monitors all error events listed in DESCRIPTION OF FUNCTIONS or [1]. Errors can be optically displayed using an NPN Darlington transistor (such as an MPSA13), a resistor R_V and an LED.

Example

For an LED with a forward voltage of 1.5V, for example, and an example diode current of 10mA the following value is produced:

$$R_V = \frac{5V - 1.5V}{10mA} = 350\Omega.$$

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The diode current is supplied by the transistor, for example (a Darlington transistor with a β value which must be selected depending on the required diode current) and is activated by the control output in the event of error.

Example application 2: OPV405 as a 4…20mA current interface circuit monitor[2]

Nature of the problem [3]:

The value of output current I_{OUT} in a 4–20mA, 2-wire current loop circuit is to be monitored and an error indicated if the thresholds <4mA and >20mA are overshot or undershot.

Possible solution:

The OPV405 operating point is set in such a way that it functions in normal operation within the current loop thresholds which are to be monitored (Vout ≥ 0.2V to Vout ≤ 4.8V). Setting the operating point means that with the help of a resistor network the current thresholds are converted into adequate voltages with which OPV405 can be driven.

A current in load resistor R_{L1} which is either too low or too high causes OPV405 to overload, triggering the control indicator.

Dimensioning the circuit:

Current I_{SS} (see *Figure 4*) is converted into a voltage by load resistor R_{L1} in the upstream current loop circuit. Through the current I_1 and the resistor R_1 this voltage influences the mean voltage between the two voltage divider resistors R_2 and R_3. This voltage is monitored by OPV405 as an input signal.

V_{CC} = 5V is given as the supply voltage. OPV405 is configured as a non-inverting operational amplifier. A minimum of v = 10 must be selected as the amplification (data sheet OPV405).

According to the equation:

$$v = \frac{R_7}{R_4 // R_5} + 1 \tag{1}$$

v = 11 is determined by way of simplification.

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Internet: http://www.analogmicro.de
Email: info@analogmicro.de

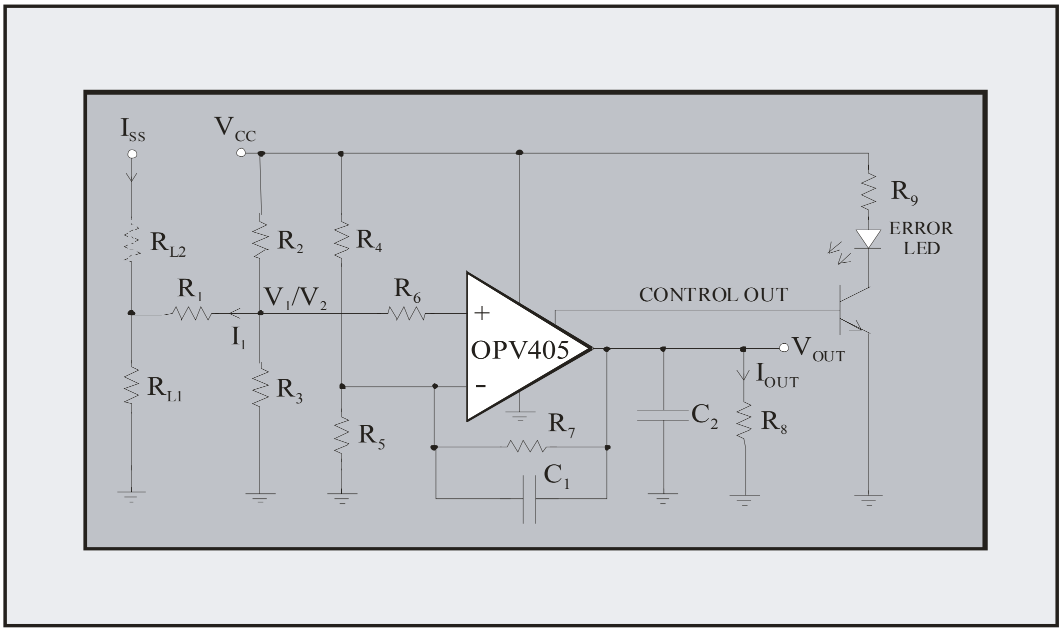

***Figure 4*: OPV405 as a 4–20mA current loop circuit monitor**

In order to reach the dynamic range of OPV405 the IC-output must be adjusted symmetrically by I_{SS} and ±2.3V from 0.5*Vcc = 2.5V. With a gain of v = 11 this yields a necessary voltage swing between R_2 and R_3 of:

$$V_{1,2} = 2.5V \pm (2.3V/11) \approx 2.5V \pm 0.21V.$$

The input voltage at the inverting input of OPV405 tracks voltage $V_{1,2}$ at the non-inverting input. The following must apply:

$$R7 \geq 10*(R4//R5)$$

As according to the specifications the maximum output current of OPV405 is fixed at 250µA and as enough current must be present to drive an output load, feedback resistor R_7 may not have too low an impedance.

R_7 = 100kΩ is selected. In accordance with equation (1), R_4, R_5 = 20 kΩ.

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To keep errors as minimal as possible due to the various bias currents the following should apply:

$$R6 = R4 \,//\, R5 \rightarrow R6 = 10k\Omega$$

As voltage divider R2, R3 is barely charged it can be selected at will. The impedance thereof should, however, neither be too high (bias current error) nor too low (quiescent circuit current).

R_2, R_3 = 10 kΩ is selected. The following must apply for the OPV405 input voltages V_1,V_2:

$$V_1 \approx 2.71V \text{ and } V_2 \approx 2.29V$$

In order to achieve these values, the currents through R_2 and R_3 must be adjusted. One of them is lowered by voltage drop I_{SS}*R_{L1} and the current through R_1, while the other is correspondingly raised. The following is then obtained with R_2 and R_3:

$$I_{R2,R3} \approx 250\mu A \pm (0.21V / 10k\Omega) \approx 250\mu A \pm 20.9\mu A$$

Accordingly this then results in a current through R_1 of $I_1 \approx 41.8\mu A$.

With voltages V_1 and V_2, the current values for I_{SS} (I_{SS1} = 4mA and I_{SS2} = 20mA) and cross current I_1 two equations are obtained for resistors R_{L1} and R_1.

$$R_1 = \frac{V_1}{I_1} - \frac{(I_{SS1} + I_1) \cdot R_{L1}}{I_1} \quad (2)$$

$$R_{L1} = \frac{I_1 \cdot R_1}{(I_{SS2} - I_1)} + \frac{V_2}{(I_{SS2} - I_1)} \quad (3)$$

Solving the system of equations in equations (2) and (3) yields the following results:

$R_1 \approx 34.65k\Omega$ and **$R_{L1} \approx 208.3\Omega$**

Voltages V_1 and V_2 are generated with these values; these trigger the function control unit within a prohibited current range of I_{SS} < 4mA and I_{SS} > 20mA.

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Analog Microelectronics GmbH
An der Fahrt 13, D – 55124 Mainz
Phone: +49 (0)6131/91 0730-0
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PINOUT/PADOUT

PIN	NAME	EXPLANATION
1	*OUT*	Output
2	*IN-*	Inverting Input
3	*IN+*	Non-Inverting Input
4	GND	IC Ground
5	*N.C.*	Not Connected
6	*N.C.*	Not Connected
7	*Control*	Control Unit Output
8	*VCC*	5V Supply Voltage

Table 3: **OPV405 pinout**

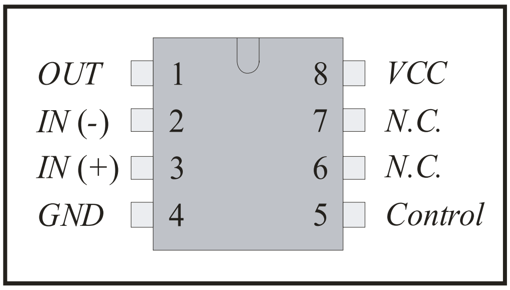

Figure 5: **OPV405 padout**

Package dimensions:

See http://www.analogmicro.de/products/analogmicro.de.en.package.pdf

DELIVERY OPTIONS

OPV405 is available as an SOP 8 package.

FURTHER READING

www.analogmicro.de:

[1] Application note AN1018: AM457-Amplification of resistor bridge circuits with integrated control functions

[2] Technical article PR1012: AM462 - A voltage-to-current converter IC for 2-wire current loop applications (4…20mA, current loop)

[3] Application note AN1016: OPV405 - Monitoring current in a 20mA (2-wire) current loop

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