Intronics Power ®

Economy, Wideband Log/Antilog Amplifiers

MODEL 759N 759P

FEATURES

Low-Cost, Complete Log/Antilog Amplifier
- **External Components Not Required;**
- **Internal Reference; Temperature Compensated**

Small Size: 1.1″ x 1.1″ x 0.4″

Fast Response: 200kHz Bandwidth (I_{SIG} = 1μA)

6 Decades Current Operation — 1nA to 1mA
- **1% max Error – 20nA to 200μA**
- **2% max Error — 10nA to 1mA**

4 Decades Voltages Operation — 1mV to 10V
- **1% max Error – 1mV to 2V**
- **2% max Error — 1mV to 10V**

APPLICATIONS

Log Current or Voltage

Antilog Voltage

Data Compression or Expansion

GENERAL DESCRIPTION

Models 759N and 759P are low cost, fast response, dc logarithmic amplifiers offering 1% conformance to ideal log operation over four decades of current operation — 20nA to 200μA, as well as 2% conformance over four decades of voltage operation – 1mV to 10V. Featuring 200kHz bandwidth at I_{SIG} = 1μA, these new economy designs are the industry's fastest log/antilog amplifiers and offer an attractive alternative to in-house designs.

Designed for ease of use, models 759N/P are complete, temperature compensated, log or antilog amplifiers packaged in a small 1.1″ x 1.1″ x 0.4″ epoxy encapsulated module. External components are not required for logging currents over the complete six decade operating range from 1nA to 1mA. Both the scale factor (K = 2, 1, 2/3 volt/decade) and log/antilog operation can be selected by simple pin interconnection. In addition both the internal 10μA reference current as well as the offset voltage may be externally adjusted to improve overall accuracy performance.

MODEL SELECTION

Model 759N computes the log of positive input signals (voltage or current), while model 759P computes the log of negative input signals (voltage or current). In the antilog mode of operation, both models accept bipolar voltage input signals ($-2V \leqslant E_{SIG}/K \leqslant 2V$), with model 759N producing a positive output signal and model 759P producing a negative output signal.

APPLICATIONS

Model 759N and 759P can operate with either current or voltage inputs when connected as shown in Figure 1. To illustrate the logarithmic transfer characteristics, a plot of input current versus output voltage is also presented. Model 759 is ideally suited for log applications whenever low cost implementation of logarithmic natural relationships is advantages. Examples are absorbence measurements, data compression and expansion, chemical analysis of liquids, computing powers, roots and ratios and conversion of exponential quantities to linear form.

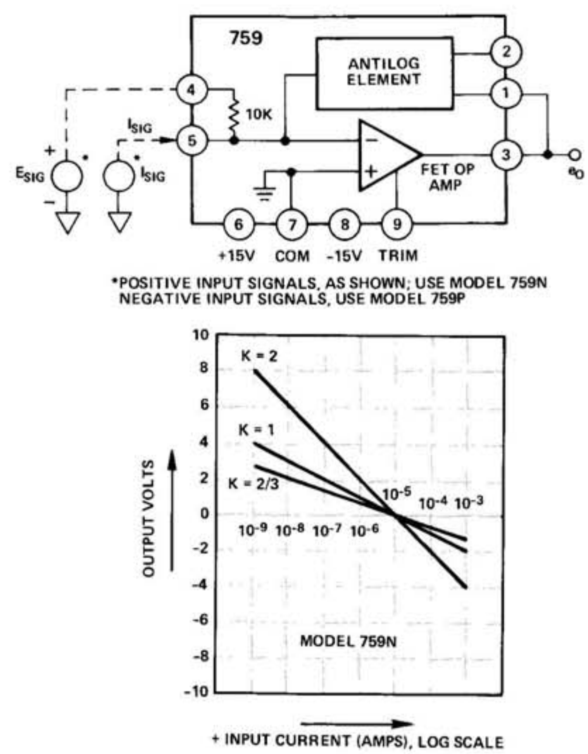

Figure 1. Functional Block Diagram and Transfer Function

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SPECIFICATIONS (typical @ +25°C and V_S = ±15V dc unless otherwise noted)

MODEL	759N/P
TRANSFER FUNCTIONS	
Current Mode	$e_O = -K\log_{10}\frac{I_{SIG}}{I_{REF}}$
Voltage Mode	$e_O = -K\log_{10}\frac{E_{SIG}}{E_{REF}}$
Antilog Mode	$e_O = E_{REF}\ 10^{-\left(\frac{E_{SIG}}{K}\right)}$
TRANSFER FUNCTION PARAMETERS	
Scale Factor (K) Selections[1, 2]	2, 1, 2/3 Volt/Decade
Error @ +25°C	±1% max
vs. Temperature (0 to +70°C)	±0.04%/°C max
Reference Voltage (E_{REF})[2]	0.1V
Error @ +25°C	±4% max
vs. Temperature (0 to +70°C)	±0.05%/°C
Reference Current (I_{REF})[2]	10µA
Error @ +25°C	±3% max
vs. Temperature (0 to +70°C)	±0.05%/°C

LOG CONFORMITY ERROR

I_{SIG} Range	E_{SIG} Range	R.T.I.	R.T.O. (K = 1)
20nA to 200µA	1mV to 2V	±1% max	±4.3mV max
10nA to 1mA	1mV to 10V	±2% max	±8.64mV max
1nA to 10nA		±5%	±21mV

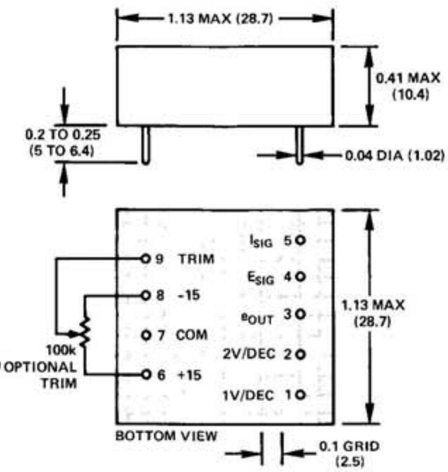
INPUT SPECIFICATIONS	
Current Signal Range	
Model 759N	+1nA to +1mA min
Model 759P	-1nA to -1mA min
Max Safe Input Current	±10mA max
Bias Current @ +25°C	(0, +) 200pA max
vs. Temperature (0 to +70°C)	x2/+10°C
Voltage Signal Range	
Model 759N	+1mV to +10V min
Model 759P	-1mV to -10V min
Offset Voltage @ +25°C (Adjustable to 0)	±2mV max
vs. Temperature (0 to +70°C)	±10µV/°C
vs. Supply Voltage	±15µV/%
FREQUENCY RESPONSE, Sinewave	
Small Signal Bandwidth, -3dB	
I_{SIG} = 1nA	250Hz
I_{SIG} = 10nA	1.8kHz
I_{SIG} = 100nA	25kHz
I_{SIG} = 1µA	200kHz
I_{SIG} = 10µA	300kHz
I_{SIG} = 100µA	300kHz
I_{SIG} = 1mA	300kHz
RISE TIME	
Increasing Input Current	
10nA to 100nA	20µs
100nA to 1µA	3µs
1µA to 100µA	2.5µs
100µA to 1mA	2.5µs
Decreasing Input Current	
1mA to 100µA	3µs
100µA to 1µA	3µs
1µA to 100nA	10µs
100nA to 10nA	80µs
INPUT NOISE	
Voltage, 10Hz to 10kHz	10µV rms
Current, 10Hz to 10kHz	10pA rms
OUTPUT SPECIFICATIONS[3]	
Rated Output	
Voltage	±10V min
Current	
Log Mode	±5mA
Antilog Mode	±4mA
Resistance	0.5Ω
POWER SUPPLY[4]	
Rated Performance	±15V dc
Operating	±(12 to 18)V dc
Current, Quiescent	±4mA
TEMPERATURE RANGE	
Rated Performance	0 to +70°C
Operating	-25°C to +85°C
Storage	-55°C to +125°C
CASE SIZE	1.125" x 1.125" x 0.4"

[1] Use terminal 1 for K = 1V/decade; terminal 2 for K = 2V/decade, terminals 1 and 2 (shorted together) for K = 2/3V/decade.
[2] Specification is + for model 759N, – for model 759P.
[3] No damage due to any pin being shorted to ground.
[4] Recommended power supply, model 904, ±15V @ ±50mA output.

Specifications subject to change without notice.

OUTLINE DIMENSIONS

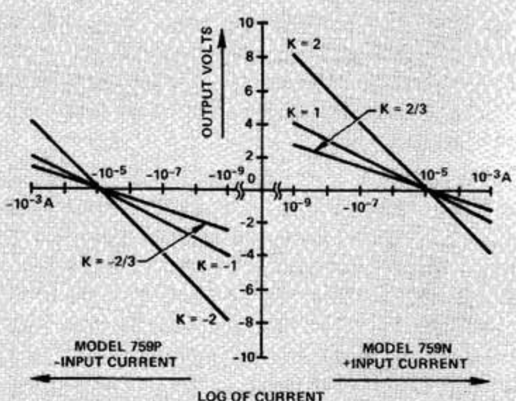
Dimensions shown in inches and (mm).



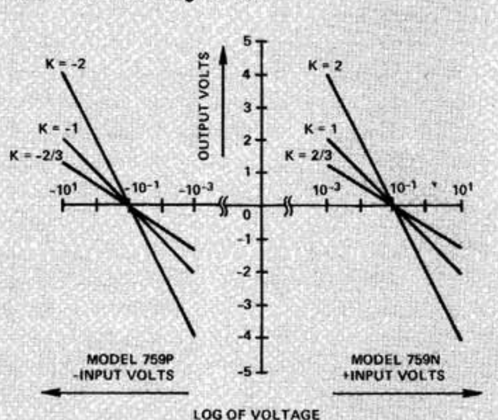
WEIGHT: 10 GRAMS
MATING SOCKET AC1016 $5.00 (1–9)

[1] Optional 100kΩ external trim pot. Input offset voltage may be adjusted to zero with trim pot connected as shown. With trim terminal 9 left open, input offset voltage will be ±2mV maximum.

TRANSFER CURVES



Plot of Output Voltage vs Input Current for Model 759 Connected in the Log Mode



Plot of Output Voltage vs Input Voltage for Model 759 Connected in the Log Mode

Understanding the Log Amplifier Performance

PRINCIPLE OF OPERATION

Log operation is obtained by placing the antilog element in the feedback loop of the op amp as shown in Figure 1. At the summing junction, terminal 5, the input signal current to be processed is summed with the output current of the antilog element. To attain a balance of these two currents, the op amp provides the required output voltage to the antilog feedback element. Under these conditions the ideal transfer equation (K = 1) is:

$$e_{OUT} = 1V \log_{10} I_{SIG}/I_{REF}$$

The log is a mathematical operator which is defined only for numbers, which are dimensionless quantities. Since an input current would have the dimensions of amperes it must be referenced to another current, I_{REF}, the ratio being dimensionless. For this purpose a temperature compensated reference of 10μA is generated internally.

The scale factor, K, is a multiplying constant. For a change in input current of one decade (decade = ratio of 10:1), the output changes by K volts. K may be selected as 1V or 2V by connecting the output to pin 1 or 2, respectively. If the output is connected to both pins 1 and 2, K will be 2/3V.

REFERRING ERRORS TO INPUT

A unique property of log amplifiers is that a dc error of any given amount at the output corresponds to a constant percent of the input, regardless of input level. To illustrate this, consider the output effects due to changing the input by 1%.

The output would be:

$$e_{OUT} = 1V \log_{10} (I_{SIG}/I_{REF})(1.01) \text{ which is equivalent to:}$$

$$e_{OUT} = \underbrace{1V \log_{10} (I_{SIG}/I_{REF})}_{\text{Initial Value}} \quad \underbrace{\pm 1V \log_{10} (1.01)}_{\text{Change}}$$

The change in output, due to a 1% input change is a constant value of ±4.3mV. Conversely, a dc error at the output of ±4.3mV is equivalent to a change at the input of 1%. An abbreviated table is presented below for converting between errors referred to output (R.T.O.), and errors referred to input (R.T.I.).

	ERROR R.T.O.		
ERROR R.T.I.	K = 1	K = 2	K = 2/3
0.1%	0.43mV	0.86mV	0.28mV
0.5	2.17	4.34	1.45
1.0	4.32	8.64	2.88
3.0	12.84	25.68	8.56
4.0	17.03	34.06	11.35
5.0	21.19	42.38	14.13
10.0	41.39	82.78	27.59

Table 1. Converting Output Error in mV to Input Error in %

SOURCES OF ERROR

Log Conformity Error – Log conformity in logarithmic devices is a specification similar to linearity in linear devices. Log conformity error is the difference between the value of the transfer equation and the actual value which occurs at the output of the log module, after scale factor, reference and offset errors are eliminated or taken into account. Figure 2 below illustrates the log conformity performance of model 759 over a 6 decade input range. The best linearity performance is obtained in the 5 decades from 10nA to 1mA. To obtain optimum performance, the input data should be scaled to this range.

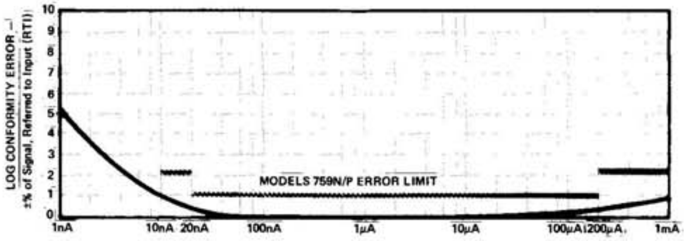


Figure 2. Log Conformity Error for Models 759N and 759P

Offset Voltage – The offset voltage, E_{os}, of model 759 is the offset voltage of the internal FET amplifier. This voltage appears as a small dc offset voltage in series with the input terminals. For current logging applications, its error contribution is negligible. However, for log voltage applications, best performance is obtained by an offset trim adjustment.

Bias Current – The bias current of model 759 is the bias current of the internal FET amplifier. This parameter can be a significant source of error when processing signals in the nanoamp region. For this reason, the bias current for model 759 is 200pA, maximum.

Reference Current – I_{REF} is the internally generated current source to which all input currents are compared. I_{REF} tolerance errors appear as a dc offset at the output. The specified value of I_{REF} is ±3% referred to the input, and, from Table 1, corresponds to a dc offset of ±12.84mV for K = 1. This offset is independent of input signal and may be removed by injecting a current into terminal 1 or 2.

Reference Voltage – E_{REF} is the effective internally generated voltage to which all input voltages are compared. It is related to I_{REF} through the equation:

$E_{REF} = I_{REF} \times R_{IN}$, where R_{IN} is an internal 10kΩ, precision resistor. Virtually all tolerance in E_{REF} is due to I_{REF}. Consequently, variations in I_{REF} cause a shift in E_{REF}.

Scale Factor – Scale factor is the voltage change at the output for a decade (i.e., 10:1) change at the input, when connected in the log mode. Error in scale factor is equivalent to a change in gain, or slope, and is specified in per cent of the nominal value. An external adjustment may be performed if fine trimming is desired for improved accuracy.

OPTIONAL EXTERNAL ADJUSTMENTS FOR LOG OPERATION

Trimming E_{OS} – The amplifier's offset voltage, E_{OS}, may be trimmed for improved accuracy with the model 759 connected in its log circuit. To accomplish this, a 100kΩ, 10 turn pot is connected as shown in Figure 3. The input terminal, Pin 4, is connected to ground. Under these conditions the output voltage is:

$$e_{OUT} = -K \log_{10} E_{OS}/E_{REF}$$

To obtain an offset voltage of 100μV or less, for K = 1, the trim pot should be adjusted until the output voltage is between +3 and +4 volts for model 759N, and -3 to -4V for model 759P.

For other values of K, the trim pot should be adjusted for an output of e_{OUT} = 3 x K to 4 x K where K is the scale factor.

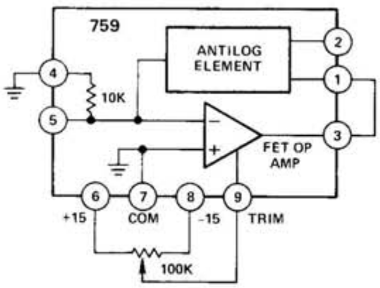


Figure 3. Trimming E_{OS} in Log Mode

Reference Current or Reference Voltage – The reference current or voltage of model 759 may be shifted by injecting a constant current into the unused scale factor terminal (Pin 1 or Pin 2). Each 330μA of current injected will shift the reference one decade, in accordance with the expression: I_I = 330μA log 10μA/I_{REF}, where I_I = current to be injected and I_{REF} = the desired reference current.

By changing I_{REF}, there is a corresponding change in E_{REF} since, $E_{REF} = I_{REF} \times R_{IN}$. An alternate method for rescaling E_{REF} is to connect an external R_{IN}, at the I_{IN} terminal (Pin 5) to supplant the 10kΩ supplied internally (leaving it unconnected). The expression for E_{REF} is then, $E_{REF} = R_{IN}\, I_{REF}$. Care must be taken to choose R_{IN} such that $(e_{SIG}\ \max)/R_{IN} \leqslant 1$mA.

Scale Factor (K) Adjustment – Scale factor may be increased from its nominal value by inserting a series resistor between the output terminal, Pin 3, and either terminal 1 or 2. The table below should be consulted when making these scale factor changes.

RANGE OF K	CONNECT SERIES R TO PIN	VALUE OF R	NOTE
2/3V to 1.01V	1	3kΩ x (K – 2/3)	use pins 1, 2
1.01V to 2.02V	1	3kΩ x (K – 1)	use pin 1
>2.02V	2	3kΩ x (K – 2)	use pin 2

Table 2. Resistor Selection Chart for Shifting Scale Factor

ANTILOG OPERATION

The model 759 may be used to develop the antilog of the input voltage when connected as shown in Figure 4. The antilog transfer function (an exponential), is:

$$e_{OUT} = E_{REF}\ 10^{-e_{IN}/K} \qquad [-2 \leqslant e_{IN}/K \leqslant 2]$$

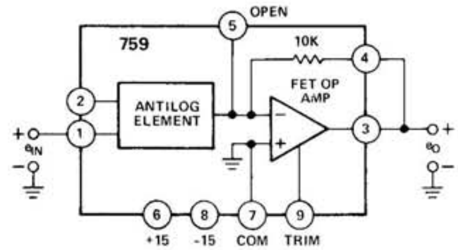


Figure 4. Functional Block Diagram

Principle of Operation – The antilog element converts the voltage input, appearing at terminal 1 or 2, to a current which is proportional to the antilog of the applied voltage. The current-to-voltage conversion is then completed by the feedback resistor in a closed-loop op amp circuit.

A more complete expression for the antilog function is:

$$e_{OUT} = E_{REF}\ 10^{-e_{IN}/K} + E_{OS}$$

The terms K, E_{OS}, and E_{REF} are those described previously in the LOG section.

Offset Voltage (E_{OS}) Adjustment – Although offset voltage of the antilog circuit may be balanced by connecting it in the log mode, and using the technique described previously, it may be more advantageous to use the circuit of Figure 5. In this configuration, offset voltage is equal to $e_{OUT}/100$. Adjust for the desired null, using the 100k trim pot. After adjusting, turn power off, remove the external 100Ω resistor, and the jumper from Pin 1 to +15V. For 759P use the same procedure but connect Pin 1 to -15V.

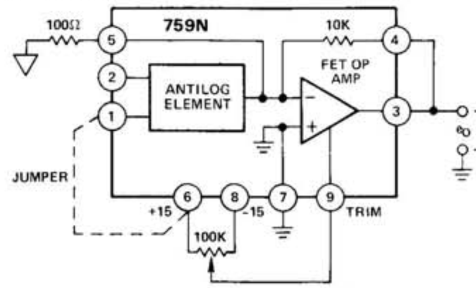


Figure 5. Trimming E_{OS} in Antilog Mode

Reference Voltage (E_{REF}) Adjustment – In antilog operation, the voltage reference appears as a multiplying constant. E_{REF} adjustment may be accomplished by connecting a resistor, R, from Pin 5 to Pin 3, in place of the internal 10kΩ. The value of R is determined by:

$$R = E_{REF}\ \text{desired}/10^{-5}\ \text{A}$$

Scale Factor (K) Adjustment – The scale factor may be adjusted for all values of K greater than 2/3V by the techniques described in the log section. If a value of K, less than 2/3V is desired for a given application, an external op amp would be required as shown in Figure 6. The ratio of the two resistors is approximately:

$$R1/R_G = (1/K - 1) \text{ where } K = \text{desired scale factor}$$

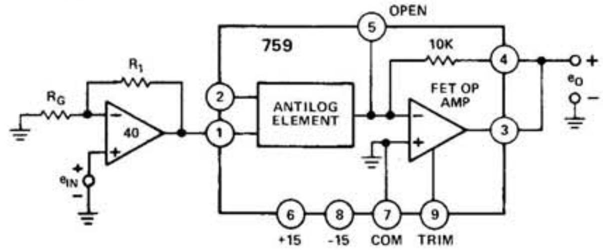


Figure 6. Method for Adjusting K<2/3V