# Voltage controlled operational amplifier BA6110FS

The BA6110FS is a low-noise, low-offset programmable operational amplifier. Offering superb linearity over a broad range, this IC is designed so that the forward direction conductivity ( $g_m$ ) can be changed, making it ideal for applications such as voltage control amplifiers (VCA), voltage control filters (VCF) and voltage control oscillators (VCO).

Distortion reduction circuitry improves the signal-to-noise ratio by a significant 10dB at a distortion rate of 0.5% in comparison with products not equipped with this feature. When used as a voltage control amplifier (VCA), a high S / N ratio of 86dB can be achieved at a distortion rate of 0.5%.

The open loop gain is determined by the control current and an attached gain determining resistance RL, enabling a wide range of settings.

In addition, a built-in low-impedance output buffer circuit reduces the number of attachments.

#### Applications

Electronic volume controls Voltage-controlled impedances Voltage-controlled amplifiers (VCA) Voltage-controlled filters (VCF) Voltage-controlled oscillators (VCO) Multipliers Sample holds Schmitt triggers

#### Features

1) Low distortion rate.

- (built-in distortion reduction bias diode)
- 2) Low noise.
- 3) Low offset voltage. (VIO = 3m VMax).

4) Built-in output buffer.

5) Variable gm with superb linearity across three decade fields.

#### Block diagram





# Internal circuit configuration



### •Absolute maximum ratings (Ta = 25°C)

Parameter	Symbol	Limits	Unit
Power supply voltage	Vcc	34	V
Power dissipation	Pd	300*1	mW
Operating temperature	Topr	- 20 ~ + 70	°C
Storage temperature	Tstg	– 55 ~ + 125	°C
Maximum control current	Іс мах.	500	μA

\*1 Reduced by 3mW for each increase in Ta of 1°C each 25°C.

### ●Electrical characteristics (unless otherwise noted, Ta = 25°C, Vcc = 15V, VEE = - 15V)

Parameter	Symbol	Min.	Тур.	Max.	Unit	Conditions	Measurement circuit
Quiescent current	la	0.9	3.0	6.0	mA	$I_{CONTROL} = 0\mu A$	Fig.2
Pin 7 bias current	I7PIN	_	0.8	5	μA	_	Fig.2
Distortion	THD	_	0.2	1	%	ICONTROL = $200\mu A$ , VI = $5mVrms$	Fig.2
Forward transmission conductance	gm	4800	8000	12000	μs	ICONTROL = 500µA	Fig.2
Pin 6 maximum output voltage	VOM6	12	14	_	V	ICONTROL = 500µA	Fig.2
Pin 8 maximum output voltage	Vom8	9	11	_	V	RL = 47kΩ	Fig.2
Pin 6 maximum output current	Іом6	300	500	650	μA	ICONTROL = 500µA	Fig.2
Residual noise 1	VN1	_	- 94	- 90	dBm	ICONTROL = 0μA, BPF (30 ~ 320kHz, 3dB, 6dB / OCT)	Fig.2
Residual noise 2	VN2	_	- 74	- 66	dBm	ICONTROL = 200μA, BPF (30 ~ 20kHz, 3dB, 6dB / OCT)	Fig.2
Discontinuous noise	VNP <sub>2</sub>	_	10.5	11.5	dB	ICONTROL = 200μA, BPF (30 ~ 20kHz, 3dB, 6dB / OCT)	Fig.2
Leakage level	L (Leak)	_	- 94	- 75	dBm	$\label{eq:loontrol} \begin{split} I_{\text{CONTROL}} &= 0 \mu A, \ V_{\text{IN}} = - \ 30 dBm \\ f_{\text{IN}} &= 20 kHz \end{split}$	Fig.2

#### Measurement circuit



#### Circuit discription

The BA6110FS is configured of an operational amplifier which can control the forward propagation conductance (gm) using the control current, an input biascompensating diode used to eliminate distortion created by the amplifier's differential input, a bias setter, and an output buffer.

In the operational amplifier, Pin 1 is the positive input and Pin 3 is the negative input. Pin 7 is the control pin which determines the differential current. Pin 11 is the output pin which determines the open loop gain using the external resistor and the control current.

This section describes the circuit operation of this operational amplifier.

Transistors Q<sub>13</sub> and Q<sub>14</sub> form the differential input for the operational amplifier, while transistors Q<sub>7</sub> to Q<sub>12</sub> are composed of the current mirror circuits. The current mirror absorbs current from the differential input common emitter which is equal to the control current flowing into the Pin 7 control pin. If the differential input V<sub>IN</sub> = 0 at this point, then 1 / 2 Ic is supplied to the Q<sub>13</sub> and Q<sub>14</sub> collectors and the other half passes through the current mirror (3) which is the differential active load is inverted by current mirror (5), and is balanced with the output of current mirror (4), also an active load.

If the differential input changes, the current balance changes. The output current is on Pin 11. An output voltage can be generated using an external resistance. For the open loop gain of this operational amplifier, if the Pin 7 control current is ICONTROL and the Pin 11 external resistance is Ro, then:

$$Av = g_m \cdot R_0 = \frac{I_{CONTROL} \times R_0}{2 \frac{KT}{q}}$$

To eliminate the distortion created by the differential input, the input bias diode and its bias circuit consist of the following: bias diodes D<sub>1</sub> and D<sub>2</sub>, current mirrors (1) and (2), and the Pin 5 bias pin current mirror that consists of the transistors Q<sub>1</sub> to Q<sub>6</sub> and the resistance R1.

This circuit eliminates the distortion that occurs as a result of using the differential input open loop.

In the buffer circuit, Pin 12 is the buffer input and Pin 14 is the buffer output.

In the buffer circuit, the emitter follower consists of the active load of the NPN transistor, Q<sub>17</sub>, and its active load, Q<sub>16</sub>. The VF difference created by the emitter follower is eliminated by the emitter follower which consists of the PNP transistor Q<sub>18</sub> and resistor R<sup>5</sup>. Also, the gain is determined by the ratio of the signal source resistance R<sub>IN</sub> and the diode impedance.

#### Attached components

#### (1) Positive input (Pin 1)

This is the differential positive input pin. To minimize the distortion due to the diode bias, an input resistor is connected in series with the signal source. By increasing the input resistance, distortion is minimized.

However, the degree of improvement for resistances greater than  $10k\Omega$  is about the same. An input resistance of  $1k\Omega$  to  $20k\Omega$  is recommended.

#### (2) Negative input (Pin 3)

This is the differential negative input pin. It is grounded with roughly the same resistance value as that of the positive input pin. The offset adjustment is also connected to this pin. Make sure a sufficiently high resistance is used, so as not to disturb the balance of the input resistance (see Figure 3).

#### (3) Input bias diode (Pin 5)

The input bias diode current (I<sub>D</sub>) is determined by this pin. The IC input impedance when the diode is biased, if the diode bias current is I<sub>D</sub>, is expressed as follows:

$$\mathsf{R}_{\mathsf{d}} = \frac{26}{\mathsf{I}_{\mathsf{D}} (\mathsf{m}\mathsf{A})} \quad (\Omega)$$

(4) Control (Pin 7)

This pin controls the differential current. By changing the current which flows into this pin, the gain of the differential amplifier can be changed.

(5) Output (Pin 11)

The differential amplifier gain (Av) is determined by the resistor Ro connected between the output terminal and the Pin 7 control terminal, as follows:

$$Av = g_{m} \cdot R_{0} = \frac{I_{CONTROL}(mA)}{52 (mV)} \times R_{0}$$

Make sure the resistor is selected based on the desired maximum output and gain.

(6) Buffer input (Pin 12)

The buffer input consists of the PNP and NPN emitter follower. The bias current is normally about  $0.8\mu$ A. Consequently, when used within a small region of control current, we recommend using the high input impedance FET buffer.

(7) Buffer output resistance (Pin 14)

An 11k $\Omega$  resistor is connected between V $\infty$  and the output within the IC. When adding an external resistance between the GND and the output, make sure the resistor R<sub>L</sub> = 33k $\Omega$ .

#### Application example

(1) Fig.3 shows a voltage-controlled amplifier (AM modulation) as an example of an application of the BA6110FS.

By changing the ICONTROL current on Pin 7, the differential gain can be changed. The gain (Av), if the resistance of Pin 11 is Ro, is determined by the following equation:

$$Av = g_m \cdot R_0 = \frac{I_{CONTROL}(mA)}{52 (mV)} \times R_c$$

Good linearity can be achieved when controlling over three decades.

By connecting Pin 5 to the Vcc by way of a resistor, the input is biased at the diode and distortion is reduced.

The gain in this case is given by the diode impedance Rd and the ratio of the input resistance  $R_{IN}$ , as shown in the following:

$$Av = g_m \cdot R_0 \times \frac{R_d}{R_d \times R_{IN}}$$

The diode impedance R<sub>d</sub> = (26 / Ib (mA))  $\Omega$ , so that the Pin 5 bias current Ib = (Vcc - 1V) / R (Pin 5). The graph in Fig. 6 shows the control current in relation to the open loop gain at the diode bias. In the same way, Fig.7 shows the control current in relation to the THD = 0.5% output at the bias point.

Fig. 8 shows a graph of the control current in relation to the open gain with no diode bias.

Fig. 9 shows a graph of the control current in relation to the SN ratio.

Fig. 10 shows a graph of the diode bias current in relation to the SN ratio.

Fig. 11 shows a graph of the power supply voltage characteristics.

(2) Fig. 4 shows a low pass filter as an example of an application of the BA6110FS.

The cutoff frequency fo can be changed by changing the Pin 7 control current.

The cutoff frequency to is expressed as:

$$f_{O} = \frac{R_{A} \cdot g_{m}}{(R + R_{A}) 2\pi C}$$

This is attenuated by -6dB / OCT.

Fig. 12 shows a graph of the ICONTROL in relation to the output characteristics.

(3) Fig. 5 shows a voltage-controlled secondary low passfilter as an example of an application of the BA6110FS.

The cutoff frequency fo can be changed by changing thePin 7 control current.

$$f_{O} = \frac{R_{A} \cdot g_{m}}{(R + R_{A}) \cdot 2\pi C}$$

This is attenuated by - 12dB / OCT.

Fig. 13 shows a graph of the ICONTROL output characteristic.



Fig.3 Voltage-controlled amplifier (electronic volume control)







Fig.5 Voltage-controlled secondary low pass filter

ROHM

# BA6110FS

# Standard ICs

- 2

- 28

FREQUENCY: f (Hz)

Fig.12 Low pass filter characteristics



FREQUENCY: f (Hz)

5k

10k 20k

50k100k

Fig.13 Secondary low pass filter characteristics

1k

- 2

- 28

100 200 500

ROHM

# BA6110FS

# Standard ICs

# •External dimensions (Units : mm)



# ROHM