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# M5207L01/M5207L05 LINEAR CONTROL DUAL VCA IC

## DESCRIPTION

The M5207L is a variable gm-type VCA (Voltage Control Amplifier) IC designed for linear controlled electronic volume control. The IC offers capability of controlling each channel independently.

Its applications include radio cassette tape recorders, car audio systems, and Hi-Fi VCR.

## FEATURES

- 2 channels of VCA with independent control terminal are built-in.
- Linear control type VCA (attenuates proportionally to the control voltage with excellent linearity).  
 ..... M5207L01 ;  $V_c = 1V_{max}$   
 ..... M5207L05 ;  $V_c = 5V_{max}$
- High maximum input voltage.....  $V_i = 8V_{rms}(THD = 1\%)$
- ATT range is large..... ATT = 0 to -100dB
- Single power source and two power source are both available COM terminal ( $V_{cc}/2$  terminals are built-in).
- High pressure proof.....  $V_{cc} = \pm 18V (36V)$
- M5207L01..... Output is set to 100% (0dB) for the input when the control voltage is 1V.
- M5207L05..... Output is set to 100% (0dB) for the input when the control voltage is 5V.



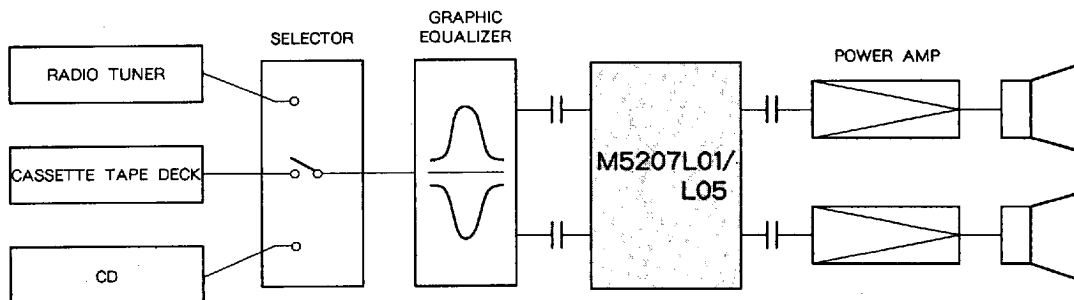
Outline 10P5

2.54mm pitch 340mil SIP  
(2.8mm x 25.23mm x 6.3mm)

## RECOMMENDED OPERATING CONDITIONS (M5207L01/M5207L05)

- Supply voltage range.....  $V_{cc}, V_{EE} = \pm 7$  to  $\pm 16V$   
 or  $V_{cc} = 4$  to  $32V$
- Rated supply voltage.....  $V_{cc}, V_{EE} = \pm 15V$  or  $V_{cc} = 9V$
- Range of linear control voltage  $V_{cc} = 0$  to  $1V, V_{EE} = 0$  to  $5V$

## SYSTEM CONFIGURATION



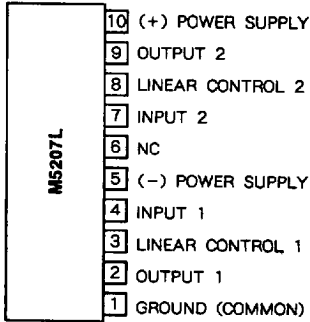
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# M5207L01/M5207L05

## LINEAR CONTROL DUAL VCA IC

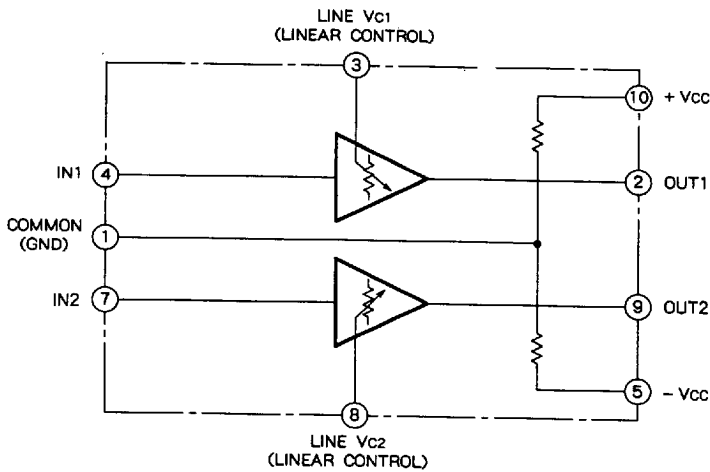
### PIN CONFIGURATION (TOP VIEW)



Outline 10P5

NC : NO CONNECTION

### IC INTERNAL BLOCK DIAGRAM



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## M5207L01/M5207L05

## LINEAR CONTROL DUAL VCA IC

## PIN DESCRIPTION

Pin No.	Name	Symbol	Function
①	COM terminal (GND)	COM (GND)	Vcc/2 is produced inside IC by resistive potential dividing and is output to terminal 1. Connect to GND when used by two power sources. Use it as a midpoint potential when used by single power source.
②	ch1 output	OUT1	This is an output terminal on ch1 side. Signal input from ch1 input terminal is output to this terminal as a current signal.
③	ch1 linear control	LINE Vc1	This is a linear control terminal on ch1 side. Output changes linearly by providing DC voltage of 0V to 1V (M5207L01) or 0V to 5V (M5207L05) between this terminal and COM terminal.
④	ch1 input	IN1	This is an input terminal on ch1 side. Input is converted into current signal by input resistor R to be input to this terminal.
⑤	(-) power	-Vcc	This is a power terminal on minus side. This has the lowest potential in this IC.
⑥	Not connected	NC	This terminal is kept OPEN.
⑦	ch2 input	IN2	This is an input terminal on ch2 side. Input is converted into current signal by input resistor R to be input to this terminal.
⑧	ch2 linear control	LINE Vc2	This is a linear control terminal on ch2 side. Output changes by providing DC voltage of 0V to 1V (M5207L01) or 0V~5V (M5207L05) between this terminal and COM terminal. Approximately 100nA is necessary as bias current.
⑨	ch2 output	OUT2	This is an output terminal on ch2 side. Signal input from ch2 input is output to this terminal as current signal.
⑩	(+) supply voltage	+Vcc	This is a power terminal on plus side.

## ABSOLUTE MAXIMUM RATINGS (Ta = 25°C, unless otherwise noted)

Symbol	Parameter	Ratings	Unit
Vcc	Supply voltage	± 18 (36)	V
Pa	Power dissipation	800	mW
Ka	Thermal derating (Ta ≥ 25°C)	8	mW/°C
Topr	Operating temperature	- 20 to + 75	°C
Tstg	Storage temperature	- 55 to + 125	°C

## ELECTRICAL CHARACTERISTICS (Ta = 25°C, Vcc = +9V, Vc (LINE) = 1V, unless otherwise noted)

## M5207L01

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
Icc	Circuit current	Vi = 0V	-	3.5	8.0	mA
VIM	Maximum input voltage	f = 1kHz, THD = 1%	2.0	2.3	-	Vrms
loo	Output offset current	Vi = 0V	-	± 0.3	± 2.0	μA
ΔATT1	Attenuation error	f = 1kHz, Vi = + 10dBm	- 1.0	0.5	2.0	dB
ΔATT2	Attenuation deviation between channels	f = 1kHz, Vi = + 10dBm	-	± 0.3	± 2.0	dB
ATTM	Linear maximum attenuation	f = 1kHz, Vi = + 10dBm, Vc (LINE) = 0V	-	- 100	- 85	dB
THD	Total harmonic distortion	f = 1kHz, Vo = 1Vrms	-	0.15	1.0	%
CS	Channel separation	f = 1kHz, BW : 10Hz to 30kHz	-	70	-	dB
HR	Hum rejection	f = 120Hz	-	57	-	dB
Vno	Output noise voltage	Vi = 0V, BW : 10Hz to 30kHz	-	60	120	μVrms

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M5207L01/M5207L05

LINEAR CONTROL DUAL VCA IC

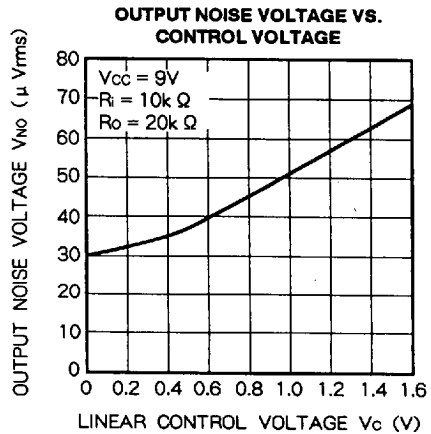
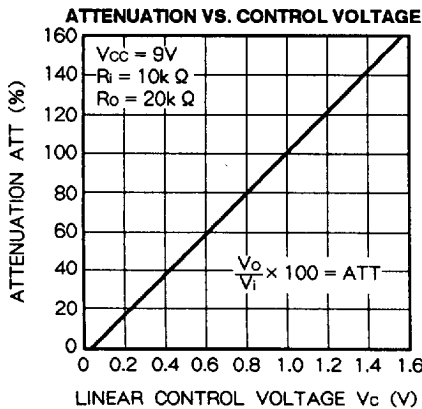
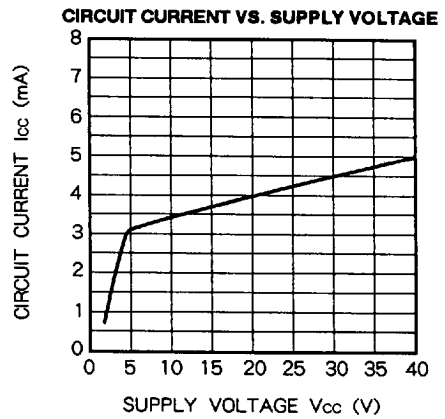
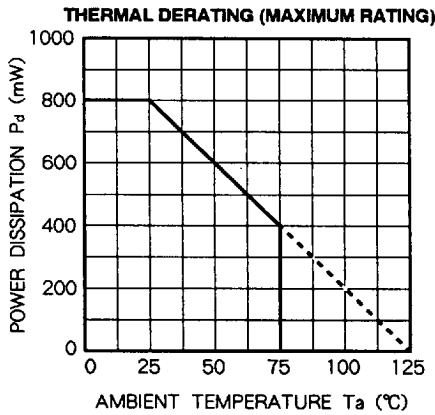
**ELECTRICAL CHARACTERISTICS** ( $T_a = 25^\circ\text{C}$ ,  $V_{CC} = \pm 15\text{V}$ ,  $V_c (\text{LINE}) = 5\text{V}$ , unless otherwise noted)

**M5207L05**

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
$I_{CC}$	Circuit current	$V_i = 0\text{V}$	-	4.3	10.0	mA
$V_{IM}$	Maximum input voltage	$f = 1\text{kHz}$ , THD = 1%	5.6	8.0	-	Vrms
$I_{OO}$	Output offset current	$V_i = 0\text{V}$	-	$\pm 0.3$	$\pm 2.0$	$\mu\text{A}$
$\Delta \text{ATT}_1$	Attenuation error	$f = 1\text{kHz}$ , $V_i = +10\text{dBm}$	-1.0	0.5	2.0	dB
$\Delta \text{ATT}_2$	Attenuation deviation between channels	$f = 1\text{kHz}$ , $V_i = +10\text{dBm}$	-	$\pm 0.3$	$\pm 2.0$	dB
$\text{ATT}_M$	Linear maximum attenuation	$f = 1\text{kHz}$ , $V_i = +10\text{dBm}$ , $V_c (\text{LINE}) = 0\text{V}$	-	-100	-85	dB
THD	Total harmonic distortion	$f = 1\text{kHz}$ , $V_o = 1\text{Vrms}$	-	0.15	1.0	%
CS	Channel separation	$f = 1\text{kHz}$ , BW: 10Hz to 30kHz	-	70	-	dB
HR	Hum rejection	$f = 120\text{Hz}$	-	57	-	dB
$V_{NO}$	Output noise voltage	$V_i = 0\text{V}$ , BW: 10Hz to 30kHz	-	60	120	$\mu\text{Vrms}$

**TYPICAL CHARACTERISTICS**

**M5207L01**

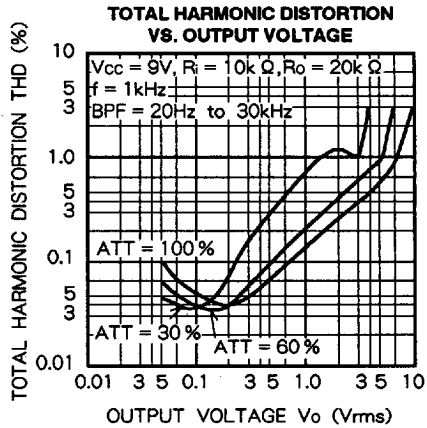
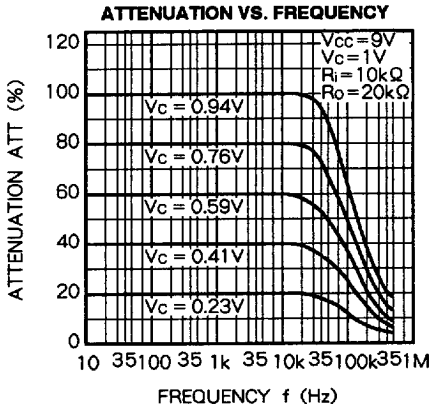


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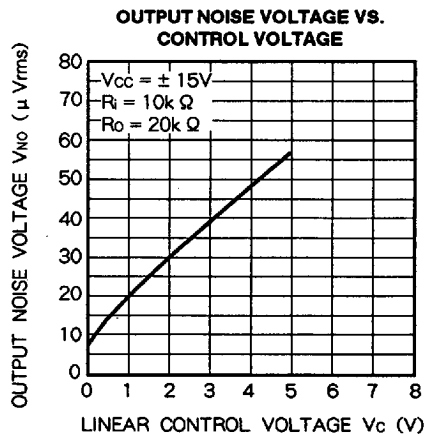
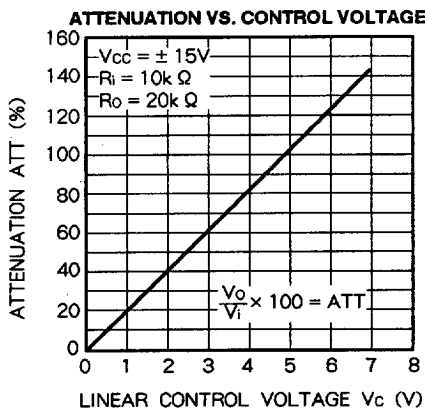
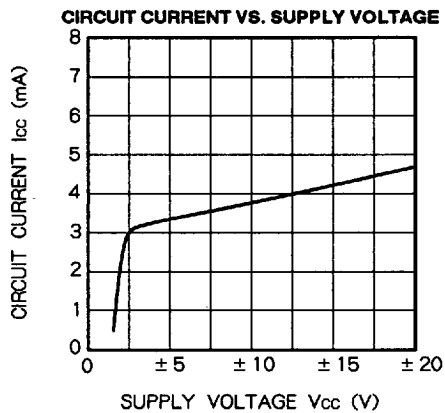
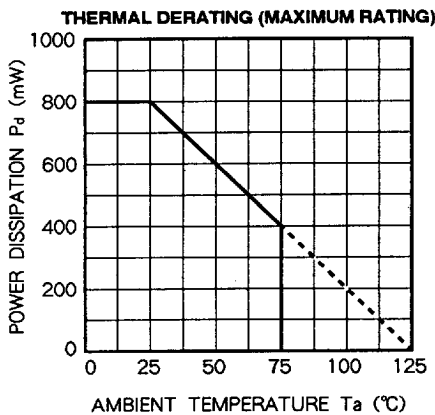


M5207L01/M5207L05

LINEAR CONTROL DUAL VCA IC

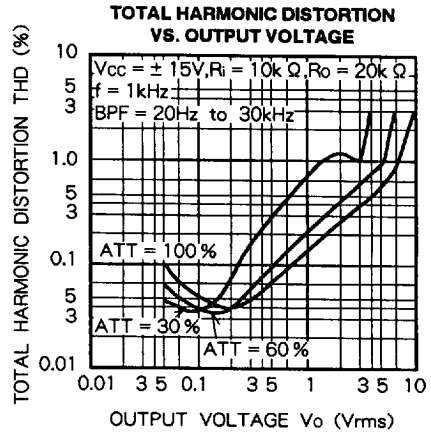
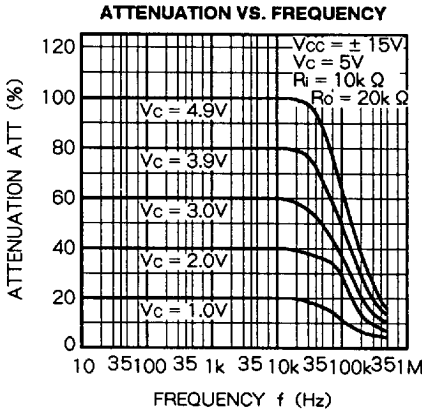


M5207L05



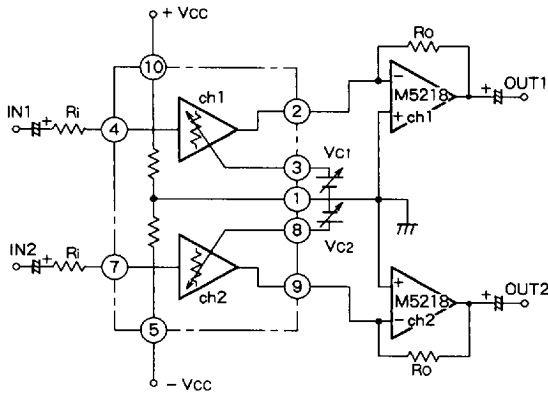
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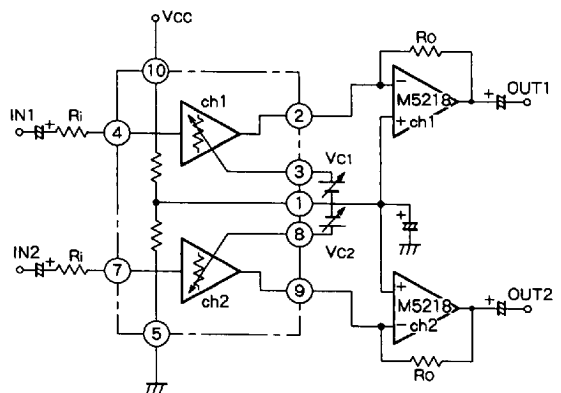


**EXAMPLE OF APPLICATION CIRCUIT**

**(1) Example of standard application circuit**

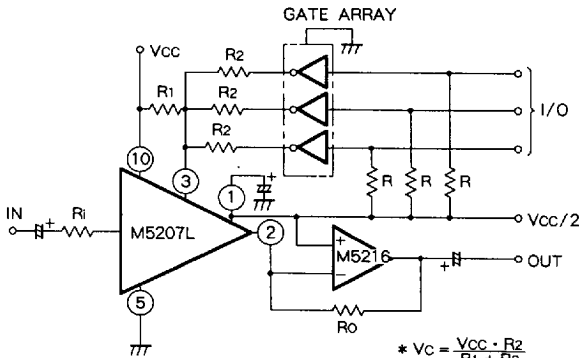


(a) 2 power sources are used



(b) Single power source is used

**(2) Example of programmable ATT circuit**



\*  $V_c = \frac{V_{cc} \cdot R_2}{R_1 + R_2}$   
 \* R is a pull-up resistor

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M5207L01/M5207L05

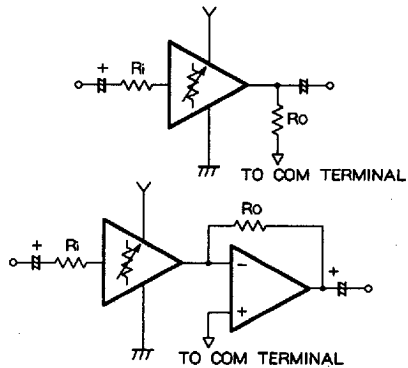
LINEAR CONTROL DUAL VCA IC

NOTES

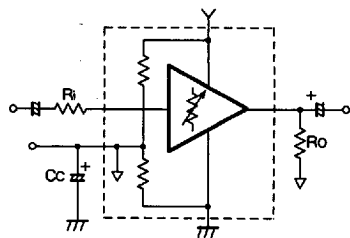
1. Internal differential circuit is balanced (when  $V_c = 5V$  for M5207L05,  $V_c = 1V$  for M5207L01) by selecting  $R_o = 2R_i$ , which makes 0dB and one time amplifier.
2. Output circuit is a float output by collector connection of transistors PNP and NPN, and it is necessary to set the potential at one end of external resistor  $R_o$ . (Refer to the section of [mechanism of I/O voltage and current conversion].)
3. M5207L uses class "A" or "B" amplifier for voltage  $\leftrightarrow$  current conversion. Maximum input current is not limited like M5222 or M5241, but there exists a maximum value because of saturation of output transistor. Therefore, it is possible to input large signal by decreasing the input current by selecting larger input and output resistance. Set the resistance value according to usages because the larger the resistance becomes, the larger the noise also becomes.
4. Voltage gain is determined by  $V_c$ ,  $R_i$  and  $R_o$ , and it may be affected by the value of input impedance connected next. ( $Z_i$  is inserted in parallel with  $R_o$  to decrease the impedance.) (See following figure)

In the circuit in Figure (a), input signal has antiphase, potential of output terminal varies by the signal, and the maximum output voltage is also affected by residual voltage in the output circuit (residual voltage of approximately 1V from  $+V_{cc}$  and  $-V_{cc}$  is generated). Whereas, in the circuit in Figure (b), input signal has equal phase, potential of output terminal is fixed, and residual voltage in the output circuit does not affect at all. Pay attention to the difference.

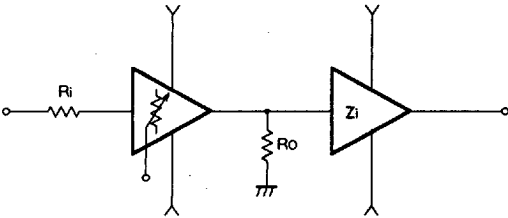
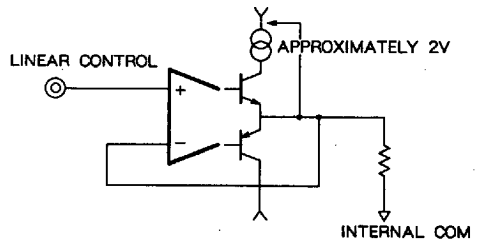
5. Note when used by single power source
  - Set one end of  $R_o$  to COMMON potential.



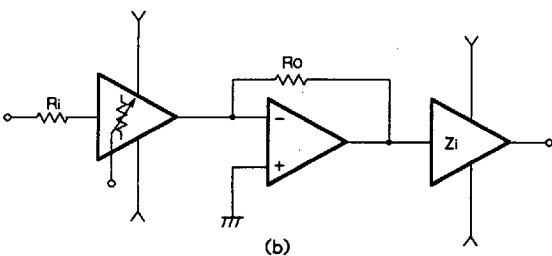
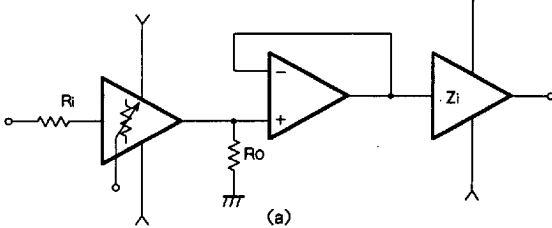
- Connect condenser  $C_c$  between COM terminal and ground to reduce impedance of COM terminal.



6. Range of supply voltage is affected largely by the range of control voltage. A stage of current mirror circuit is connected to the output push-pull circuit of control circuit and residual voltage of 2V from  $V_{cc}$  at the lowest is necessary, which means  $V_{cc} \geq V_c + 2V$ . 2V at the lowest is enough for operation of  $-V_{cc}$ .



Usually, buffer amplifier of transistor or operational amplifier is connected. (See following figures (a), (b))



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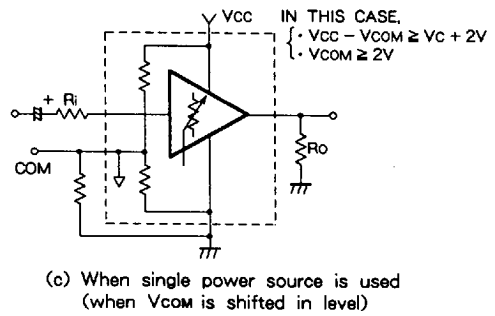
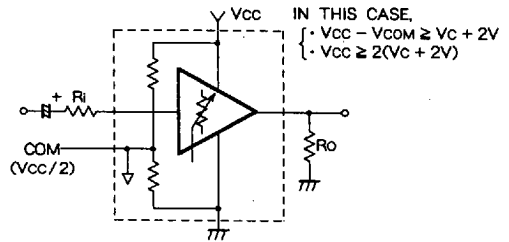
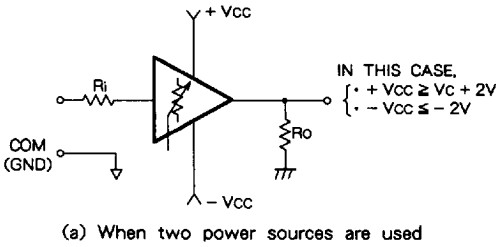


M5207L01/M5207L05

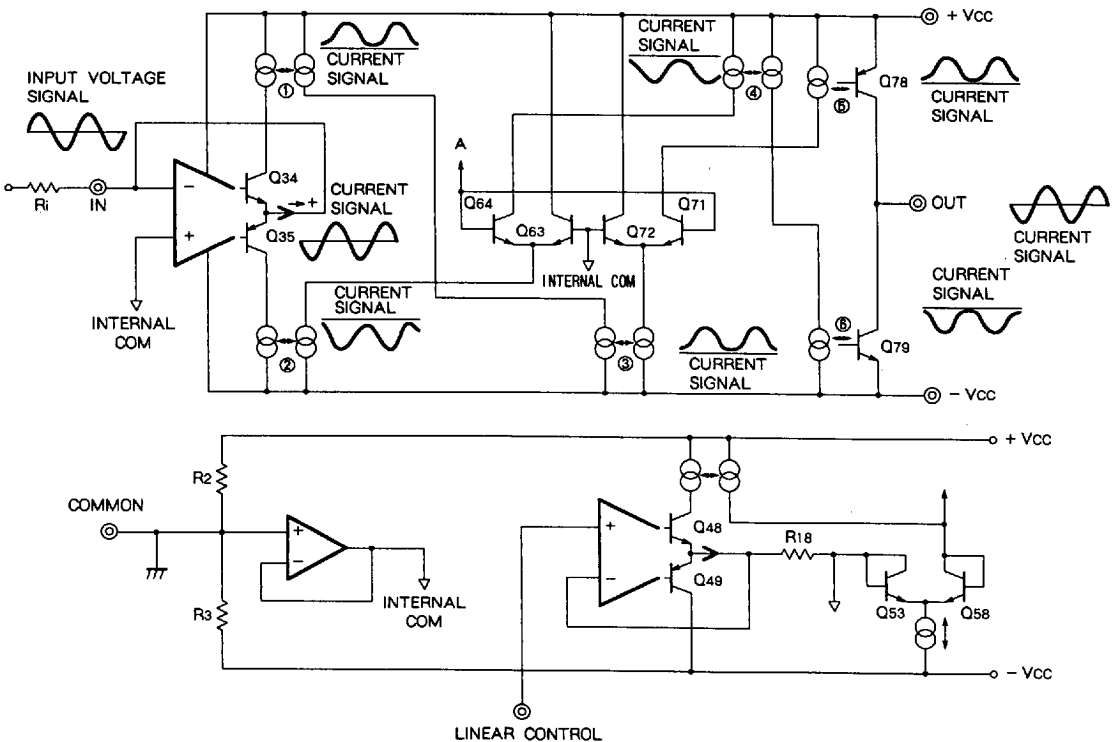
LINEAR CONTROL DUAL VCA IC

This IC incorporates a midpoint voltage generator. Set  $V_{cc} - V_{com}$  ( $V_{com}$  is usually  $V_{cc}/2$ ) larger than  $V_c + 2V$  when used by single power source.

2V potential  $V_{com}$  from ground to COMMON terminal is enough for operation. It is also possible to set  $V_{cc}$  low by shifting the level of  $V_{com}$  by an external resistor.



OPERATION CIRCUIT



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**BASIC PRINCIPLE OF OPERATION**

M5207L is a VCA (Voltage Controlled Amplifier) IC which inputs current and outputs current. This IC converts input signal to current signal by an external input resistor and sends to the current mirror output circuit through differential circuit. This current signal is converted again to voltage signal by an external output resistor and works as voltage input or voltage output apparently. Attenuation is controlled by control voltage  $V_c$  by changing balance in differential circuit (changing gm).

Its basic principle of operation is explained briefly in the following.

**1. Mechanism of I/O voltage and current conversion**

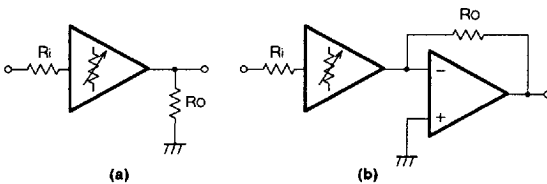
Input circuit is a voltage and current conversion circuit using operational amplifier as shown in the block diagram. Input voltage  $V_i$  is sent inside the IC as input current  $i_i = V_i/R_i$  by an external resistor  $R_i$ . (Phase is reversed.) The current sent is divided into half waves by push-pull circuit (Q34, Q35) in the input operational amplifier and is sent to the output circuit as current signal by current mirrors ①~⑥ and differential circuits (Q63, Q64, Q71, Q72).

Output circuit forms a current composition circuit using current mirrors and the composed current signal is obtained at the output terminal.

This current signal is obtained as output signal  $V_o$  by the external output resistor.

It is, however, necessary to set DC electric potential at one end of output resistor because the output circuit is a float circuit by collector connection of PNP and NPN transistors.

There are two methods for the setup: set  $R_o$  terminal to equal potential to COM (GND when two power sources are used); set by current and voltage conversion circuit using operational amplifier, as shown in the following figures.



Note that the output signal obtained in (a) has antiphase to the input signal and that in (b) has equal phase to the input signal.

**2. Mechanism in attenuation**

Output is controlled by adding positive voltage for COM terminal to  $V_c$  terminal.

Change the current allocation of differential circuit and gain of this circuit by providing a fixed potential to one base (Q63, Q72) of differential circuit from COM terminal and

providing control voltage  $V_c$  to another base (Q64, Q71) through the control circuit.

When external control voltage is provided to the bases of Q64 and Q71 directly, attenuation vs control voltage characteristic changes indexically as explained in the following, but the characteristic is converted to linear characteristic by inserting a control circuit.

This is the main feature of this IC.

**(1) Basic mechanism of attenuation**

Input signal  $V_i$  is converted to current signal  $i_i (= \frac{V_i}{R_i})$  by input resistor  $R_i$ .

This current is divided into half waves by push-pull circuit Q34 and Q35 and each is sent to the differential circuit by current mirrors ①, ②, ③.

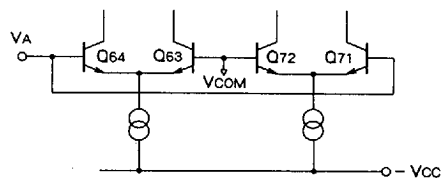
When the differential circuit is balanced (base potentials are equal), collector current of Q63 and Q64, Q71 and Q72 becomes equal and the current sent by current mirrors ①, ②, ③ is divided equally here. This current is sent to the output terminal by current mirrors ④, ⑤, ⑥ and half waved currents are compounded and output current  $i_i/2$  is obtained.

Here, select  $R_o = 2R_i$  to get

$$V_o = i_i/2 \cdot R_o = i_i/2 \cdot 2R_i = i_i \cdot R_i = V_i$$

which means an amplifier with gain 1.

Let's see attenuation characteristics with this resistance selection when COM potential is provided to the bases of Q63 and Q72 and  $V_A$  to the bases of Q64 and Q71. Current signal divided into half waves by push-pull circuit is expressed in  $i_i+$  and  $i_i-$  ( $i_i = i_i+ + i_i-$ )



Each value of  $V_{BE}$  in the differential stage is:

$$V_{BE63} \approx \frac{kt}{q} \ln \left( \frac{I_{C63}}{I_s} \right)$$

$$V_{BE64} \approx \frac{kt}{q} \ln \left( \frac{I_{C64}}{I_s} \right)$$

$$V_{BE71} \approx \frac{kt}{q} \ln \left( \frac{I_{C71}}{I_s} \right)$$

$$V_{BE72} \approx \frac{kt}{q} \ln \left( \frac{I_{C72}}{I_s} \right)$$

$k$ : Boltzman's constant  
 $T$ : Absolute temperature  
 $q$ : Electric charge  
 $I_s$ : Saturation current

The above equations result in

$$\Delta V_{BE} = V_A - V_{COM}$$

$$= V_{BE64} - V_{BE63} = \frac{kt}{q} \ln \left( \frac{I_{C64}}{I_{C63}} \right)$$

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LINEAR CONTROL DUAL VCA IC

$$= V_{BE71} - V_{BE72} = \frac{kt}{q} \ln \left( \frac{I_{C71}}{I_{C72}} \right)$$

Here,

$$I_{C63} + I_{C64} = I_i +$$

$$I_{C71} + I_{C72} = I_i -$$

Therefore,

$$V_A - V_{COM} = \frac{kt}{q} \ln \frac{I_{C64}}{I_i - I_{C64}}$$

$$V_A - V_{COM} = \frac{kt}{q} \ln \frac{I_{C71}}{I_i - I_{C71}}$$

It is supposed that  $V_{COM} = 0$  to simplify the equation because  $V_{COM} = 0V$  when two power sources are output terminal :

Therefore,

$$I_{C64} = I_i - \frac{\exp\left(\frac{q}{kt} \cdot V_A\right)}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

$$= I_i - \frac{1}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

$$I_{C71} = I_i + \frac{1}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

And current shown in the following equation flows to the output terminal :

$$I_o = I_{C78} + I_{C79}$$

$$= I_{C64} + I_{C71} = \frac{I_i}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

whose gain is :

$$\frac{V_o}{V_i} = \frac{I_o \cdot R_o}{I_i \cdot R_i} = \frac{I_o \cdot 2R_o}{I_i \cdot R_i} = \frac{2}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

Convert is into dB :

$$ATT = 20 \log \left( \frac{2}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)} \right)$$

ATT = 0dB when  $V_A = 0$

$$\text{When } 1 \ll \exp\left(-\frac{q}{kt} \cdot V_A\right)$$

$$ATT \approx -\frac{20}{\ln 10} \cdot \left(-\frac{q}{kt} \cdot V_A\right) + 20 \log 2$$

and this shows that attenuation characteristic changes indexically for  $V_c$  change.

**(2) Linear control mechanism**

Attenuation changes indexically for the potential difference of bases in differential circuit as explained above. Attenuation for control voltage changes linearly by providing control voltage through the linear control circuit.

Control circuit consists of operational amplifier, current mirrors and differential circuits as shown in the block diagram.

First, control voltage  $V_c$  provided is converted into control

current  $I_c$  by  $R_{18}$ .

$$I_c = \frac{V_c}{R_{18}}$$

And differential circuits  $Q_{53}$  and  $Q_{58}$  are biased by

constant current  $I$ , When  $I_{C53} = I_{C58} = \frac{1}{2}$

the differential circuit is balanced. (when  $V_c = 5V$  for M5207L05, and  $V_c = 1V$  for M5207L01)

This means that the potential  $V_A$  at point A becomes equal to that of  $V_{COM}$

$$V_A = V_{COM} - V_{BE53} + V_{BE58} = V_{COM}$$

Comparing it with the former section, attenuation becomes 0dB or one time gain. Suppose that control voltage  $V_c$  is added to the linear control terminal here.

Each value of  $V_{BE}$  in the differential circuit here is :

$$V_{BE53} \approx \frac{kt}{q} \ln \frac{I_{C53}}{I_s}$$

$$V_{BE58} \approx \frac{kt}{q} \ln \frac{I_{C58}}{I_s}$$

$$V_A - V_{COM} = V_{BE58} - V_{BE53} = \frac{kt}{q} \ln \frac{I_{C58}}{I_{C53}}$$

It is supposed that  $V_{COM} = 0$  to simplify the equation because  $V_{COM}$  is 0V when two power sources are used.

$$V_A = \frac{kt}{q} \ln \frac{I_{C58}}{I_{C53}}$$

And  $I_{C53}$  and  $I_{C58}$  are respectively :

$$I_{C53} = I_c = \frac{V_c}{R_{18}}$$

$$I_{C58} = I - I_{C53} = I - \frac{V_c}{R_{18}}$$

and

$$V_A = \frac{kt}{q} \ln \frac{I - \frac{V_c}{R_{18}}}{\frac{V_c}{R_{18}}} \text{ is obtained.}$$

Substitute it for the equation of gain obtained in the former section :

$$\begin{aligned} \frac{V_o}{V_i} &= \frac{2}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)} \\ &= \frac{2}{1 + \exp\left(-\frac{q}{kt} \cdot \frac{kt}{q} \ln \frac{I - \frac{V_c}{R_{18}}}{\frac{V_c}{R_{18}}}\right)} \\ &= \frac{2}{1 \cdot R_{18} \cdot V_c} \end{aligned}$$

and excellent temperature characteristic and attenuation proportional to  $V_c$  can be obtained.

This control circuit also has a system to compensate for short of attenuation (gain does not become 0 when  $V_c = 0$ ) by offset voltage of differential circuit.

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