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 ; Vc = 1Vmax
  M5207L05 ; Vc = 5Vmax
- High maximum input voltage·······V_i = 8Vrms(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} = ± 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 × 25.23mm × 6.3mm)

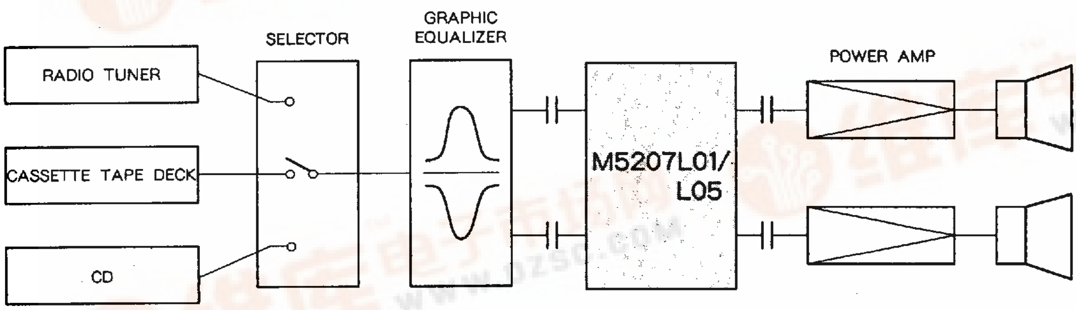
RECOMMENDED OPERATING CONDITIONS (M5207L01/M5207L05)

Supply voltage range····················V_{CC}, V_{EE} = ± 7 to ± 16V
or V_{CC} = 4 to 32V

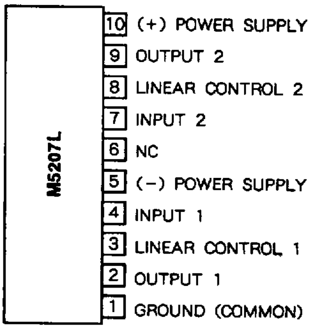
Rated supply voltage··········V_{CC}, V_{EE} = ± 15V or V_{CC} = 9V

Range of linear control voltageV_{CC} = 0 to 1V, V_{EE} = 0 to 5V

SYSTEM CONFIGURATION



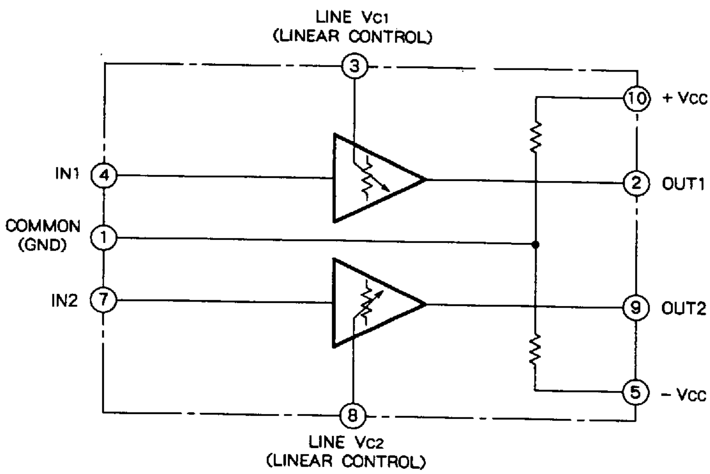
PIN CONFIGURATION (TOP VIEW)



Outline 10P5

NC : NO CONNECTION

IC INTERNAL BLOCK DIAGRAM



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 V_{C1}	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 V_{C2}	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 neccessary 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℃, unless otherwise noted)

Symbol	Parameter	Ratings	Unit
V_{CC}	Supply voltage	± 18 (36)	V
P_d	Power dissipation	800	mW
K_θ	Thermal derating (Ta ≧ 25℃)	8	mW/℃
T_{opr}	Operating temperature	− 20 to + 75	℃
T_{stg}	Storage temperature	− 55 to + 125	℃

ELECTRICAL CHARACTERISTICS (Ta = 25℃, Vcc = + 9V, $V_{C\,(LINE)}$ = 1V, unless otherwise noted)

M5207L01

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
I_{CC}	Circuit current	V_i = 0V	−	3.5	8.0	mA
V_{IM}	Maximum input voltage	f = 1kHz, THD = 1 %	2.0	2.3	−	Vrms
I_{OO}	Output offset current	V_i = 0V	−	± 0.3	± 2.0	μ A
Δ ATT_1	Attenuation error	f = 1kHz, V_i = + 10dBm	− 1.0	0.5	2.0	dB
Δ ATT_2	Attenuation deviation between channels	f = 1kHz, V_i = + 10dBm	−	± 0.3	± 2.0	dB
ATT_M	Linear maximum attenuation	f = 1kHz, V_i = + 10dBm, $V_{C\,(LINE)}$ = 0V	−	− 100	− 85	dB
THD	Total harmonic distortion	f = 1kHz, V_o = 1Vrms	−	0.15	1.0	%
CS	Channel separation	f = 1kHz, BW : 10Hz to 30kHz	−	70	−	dB
HR	Hum rejection	f = 120Hz	−	57	−	dB
V_{NO}	Output noise voltage	V_i = 0V, BW : 10Hz to 30kHz	−	60	120	μ Vrms

ELECTRICAL CHARACTERISTICS (Ta = 25℃, V_{CC} = ± 15V, $V_{C\ (LINE)}$ = 5V, unless otherwise noted)

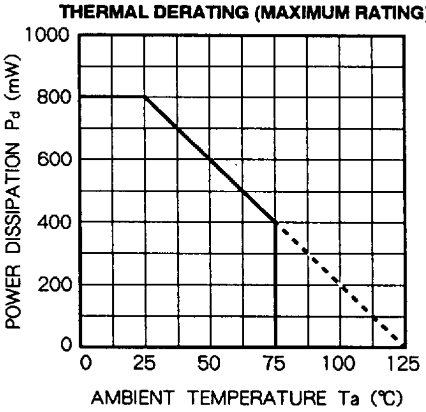
M5207L05

Symbol	Parameter	Test conditions	Limits Min	Limits Typ	Limits Max	Unit
I_{CC}	Circuit current	V_i = 0V	–	4.3	10.0	mA
V_{IM}	Maximum input voltage	f = 1kHz, THD = 1 %	5.6	8.0	–	Vrms
I_{OO}	Output offset current	V_i = 0V	–	± 0.3	± 2.0	μ A
Δ ATT_1	Attenuation error	f = 1kHz, V_i = + 10dBm	– 1.0	0.5	2.0	dB
Δ ATT_2	Attenuation deviation between channels	f = 1kHz, V_i = + 10dBm	–	± 0.3	± 2.0	dB
ATT_M	Linear maximum attenuation	f = 1kHz, V_i = + 10dBm, $V_{C\ (LINE)}$ = 0V	–	– 100	– 85	dB
THD	Total harmonic distortion	f = 1kHz, V_O = 1Vrms	–	0.15	1.0	%
CS	Channel separation	f = 1kHz, BW : 10Hz to 30kHz	–	70	–	dB
HR	Hum rejection	f = 120Hz	–	57	–	dB
V_{NO}	Output noise voltage	V_i = 0V, BW : 10Hz to 30kHz	–	60	120	μ Vrms

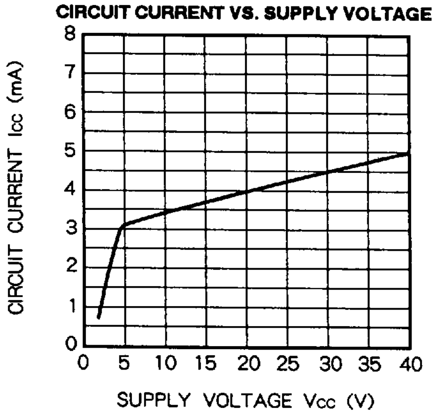
TYPICAL CHARACTERISTICS

M5207L01

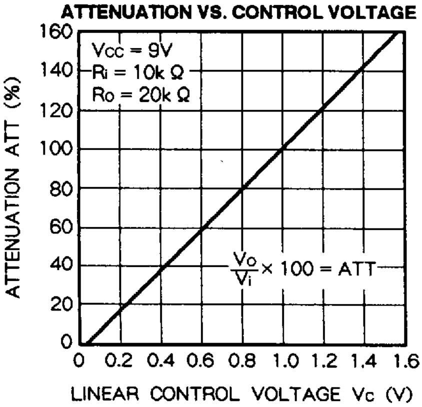
THERMAL DERATING (MAXIMUM RATING)



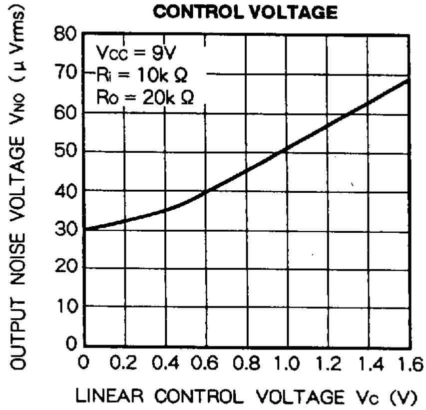
CIRCUIT CURRENT VS. SUPPLY VOLTAGE

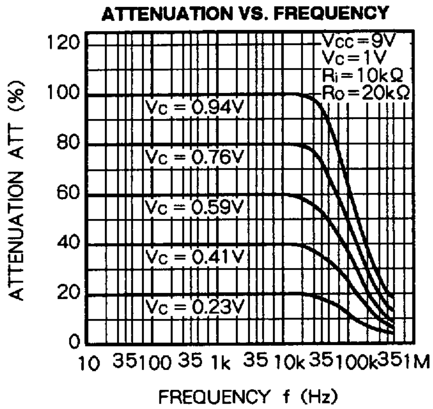


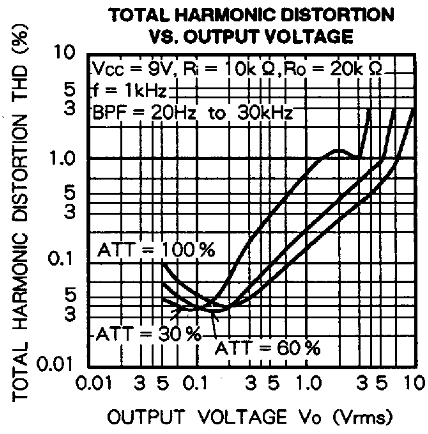
ATTENUATION VS. CONTROL VOLTAGE



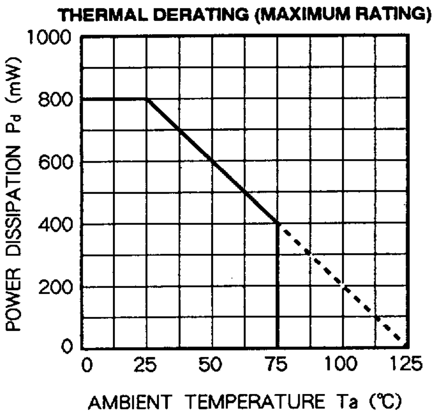
OUTPUT NOISE VOLTAGE VS. CONTROL VOLTAGE

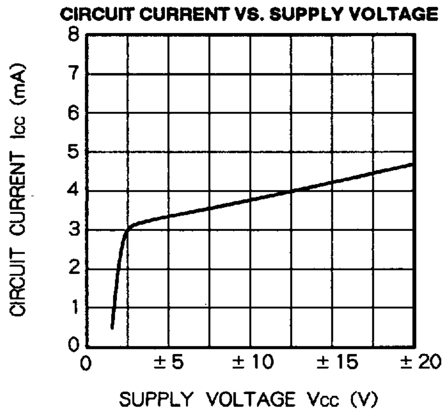


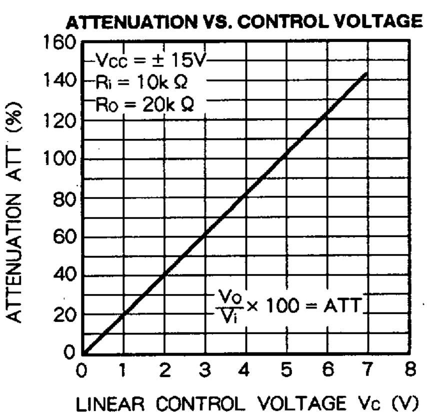

ATTENUATION VS. FREQUENCY
Vcc=9V
Vc=1V
Ri=10kΩ
Ro=20kΩ
Vc = 0.94V
Vc = 0.76V
Vc = 0.59V
Vc = 0.41V
Vc = 0.23V
ATTENUATION ATT (%)
FREQUENCY f (Hz)

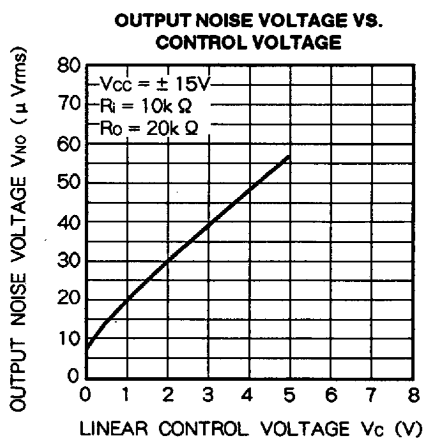

TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE
Vcc = 9V, Ri = 10k Ω, Ro = 20k Ω
f = 1kHz
BPF = 20Hz to 30kHz
ATT = 100 %
ATT = 30 %
ATT = 60 %
TOTAL HARMONIC DISTORTION THD (%)
OUTPUT VOLTAGE Vo (Vrms)

M5207L05

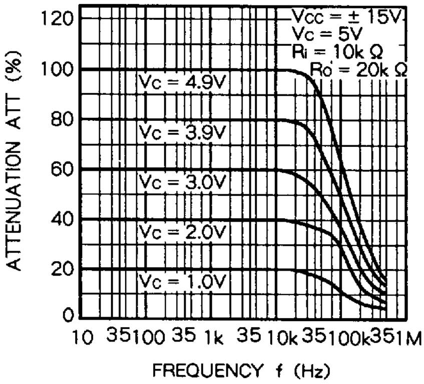

THERMAL DERATING (MAXIMUM RATING)
POWER DISSIPATION Pd (mW)
AMBIENT TEMPERATURE Ta (℃)


CIRCUIT CURRENT VS. SUPPLY VOLTAGE
CIRCUIT CURRENT Icc (mA)
SUPPLY VOLTAGE Vcc (V)

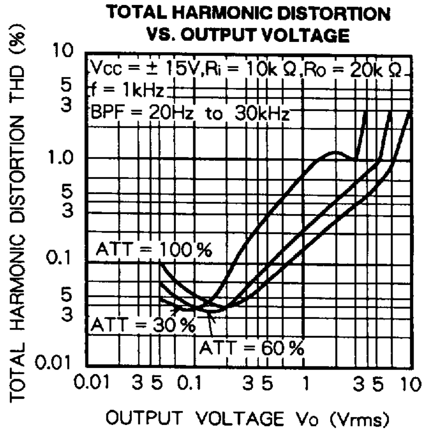

ATTENUATION VS. CONTROL VOLTAGE
Vcc = ± 15V
Ri = 10k Ω
Ro = 20k Ω
Vo/Vi × 100 = ATT
ATTENUATION ATT (%)
LINEAR CONTROL VOLTAGE Vc (V)


OUTPUT NOISE VOLTAGE VS. CONTROL VOLTAGE
Vcc = ± 15V
Ri = 10k Ω
Ro = 20k Ω
OUTPUT NOISE VOLTAGE VNO (μ Vrms)
LINEAR CONTROL VOLTAGE Vc (V)

ATTENUATION VS. FREQUENCY

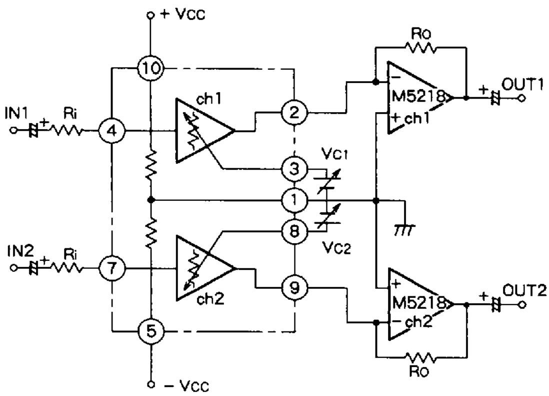


TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE

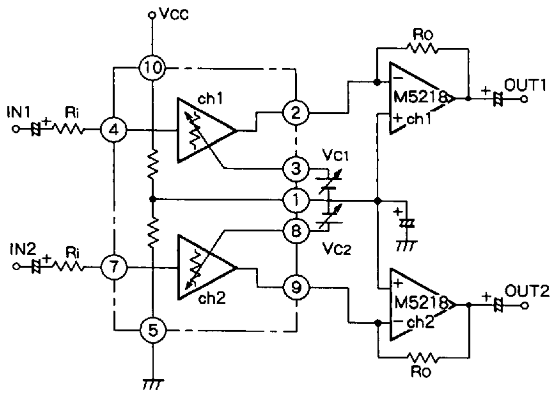


EXAMPLE OF APPLICATION CIRCUIT

(1) Example of standard application circuit

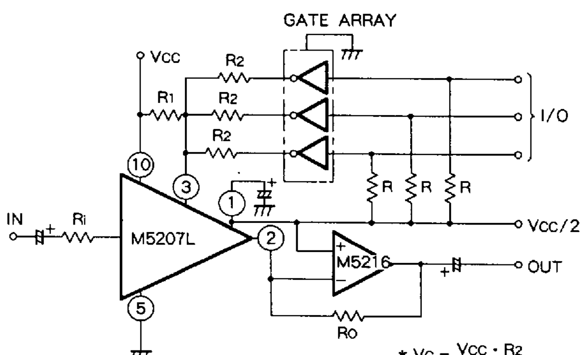


(a) 2 power sources are used



(b) Single power source is used

(2) Example of programmable ATT circuit

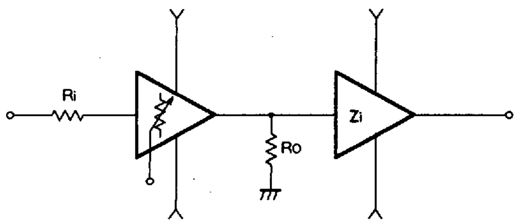


$* \; Vc = \frac{Vcc \cdot R2}{R1 + R2}$

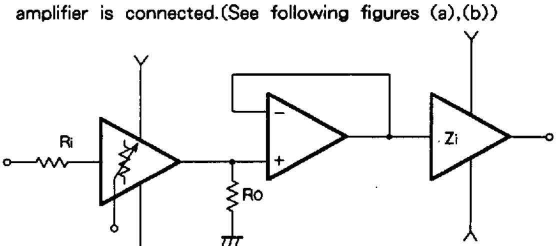
* R is a pull-up resistor

NOTES

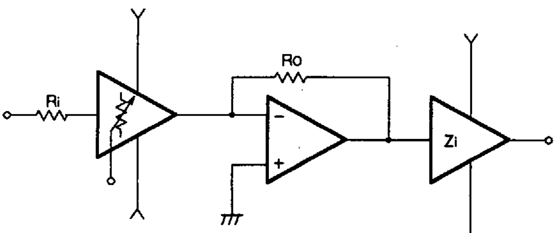
1. Internal differential circuit is balanced (when Vc = 5V for M5207L05, Vc = 1V for M5207L01) by selecting Ro = 2Ri, which makes 0dB and one time amplifier.
2. Output circuit is a float output by collector connection of transistors PNP and NPN, and it is necessary to set the potential at one end of external resistor Ro. (Refer to the section of [mechanism of I/O voltage and current conversion].)
3. M5207L uses class "A" or "B" amplifier for voltage ↔ 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 Vc, Ri and Ro, and it may be affected by the value of input impedance connected next.(Zi is inserted in parallel with Ro to decrease the impedance.) (See following figure)



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



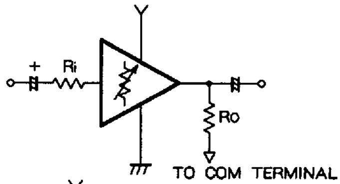
(a)

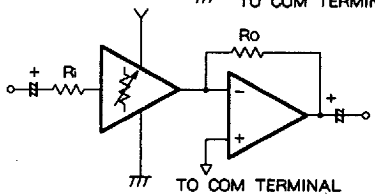


(b)

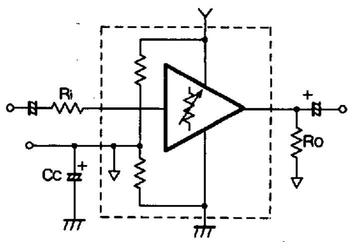
In the circuit in Figure (a), input signal has antiphase, potential of output terminal varies by the signal, and the maximum output voltage is also affected by residual voltage in the output circuit (residual voltage of approximately 1V from + Vcc and − Vcc is generated). Whereas, in the circuit in Figure (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 Ro to COMMON potential.

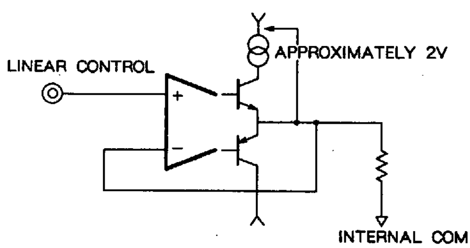




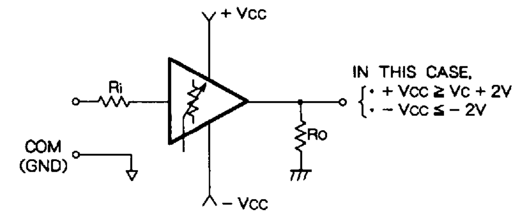
   - Connect condenser Cc between COM terminal and ground to reduce impedance of COM terminal.



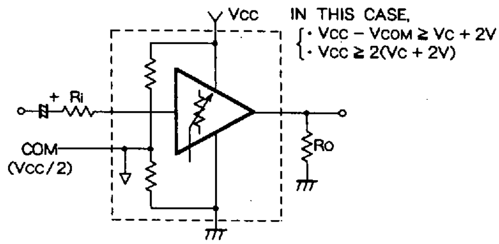
6. Range of supply voltage is affected largely by the range of control voltage. A stage of current mirror circuit is connected to the output push-pull circuit of control circuit and residual voltage of 2V from Vcc at the lowest is necessary, which means Vcc ≥ Vc + 2V. 2V at the lowest is enough for operation of − Vcc.



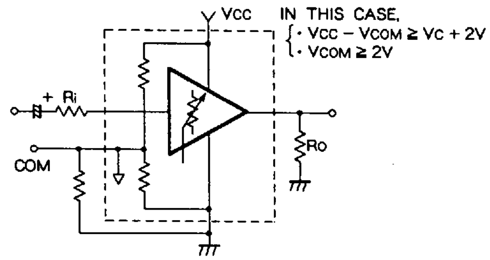
This IC incorporates a midpoint voltage generator. Set Vcc − VCOM (VCOM is usually Vcc/2) larger than Vc + 2V when used by single power source.
2V potential VCOM from ground to COMMON terminal is enough for operation. It is also possible to set Vcc low by shifting the level of VCOM by an external resistor.



(a) When two power sources are used

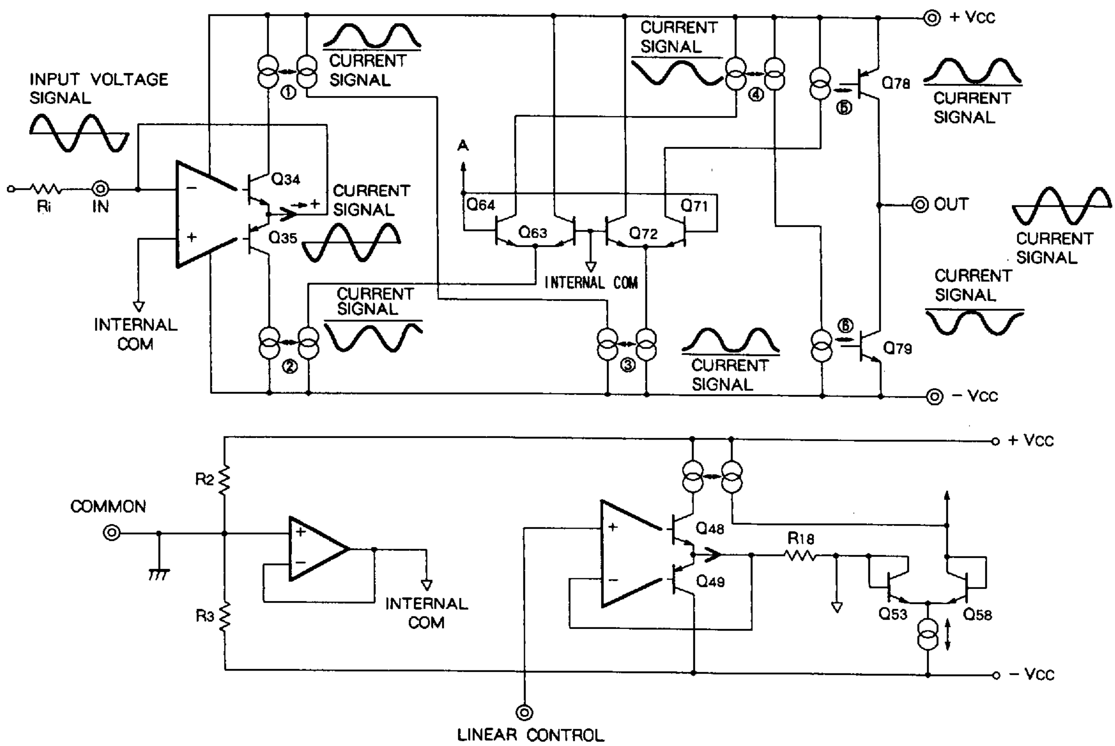


(b) When single power source is used (with no modification)



(c) When single power source is used (when VCOM is shifted in level)

OPERATION CIRCUIT



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 Vc 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

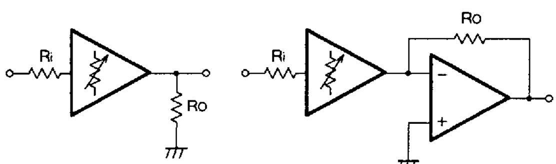
Input circuit is a voltage and current conversion circuit using operational amplifier as shown in the block diagram. Input voltage V_i is sent inside the IC as input current $i_i = V_i/R_i$ by an external resistor R_i.(Phase is reversed.) The current sent is divided into half waves by push-pull circuit (Q_{34}, Q_{35}) in the input operational amplifier and is sent to the output circuit as current signal by current mirrors ①~⑥ and differential circuits (Q_{63}, Q_{64}, Q_{71}, Q_{72}).

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 Vo 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 Ro 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.



(a) (b)

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

2. Mechanism in attenuation

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

Change the current allocation of differential circuit and gain of this circuit by providing a fixed potential to one base (Q_{63}, Q_{72}) of differential circuit from COM terminal and providing control voltage Vc to another base (Q_{64}, Q_{71}) through the control circuit.

When external control voltage is provided to the bases of Q_{64} and Q_{71} directly, attenuation vs control voltage characteristic changes indexically as explained in the following, but the chraracteristic 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 ($=\frac{V_i}{R}$) by input resistor R_i.

This current is divided into half waves by push-pull circuit Q_{34} and Q_{35} and each is sent to the differential circuit by current mirrors ①, ②, ③.

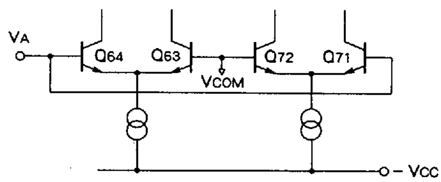
When the differential circuit is balanced (base potentials are equal), collector current of Q_{63} and Q_{64}, Q_{71} and Q_{72} becomes equal and the current sent by current mirrors ①, ②, ③ is divided equally here. This current is sent to the output terminal by current mirrors ④, ⑤, ⑥ and half waved 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 Q_{63} and Q_{72} and V_A to the bases of Q_{64} and Q_{71}. 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 :

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

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

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

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

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

The above equations result in

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

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

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,

$$I_{C64} = i_{i-} \cdot \frac{\exp(\frac{q}{kt} \cdot V_A)}{1 + \exp(-\frac{q}{kt} \cdot V_A)}$$

$$= i_{i-} \cdot \frac{1}{1 + \exp(-\frac{q}{kt} \cdot V_A)}$$

$$I_{C71} = i_{i+} \cdot \frac{1}{1 + \exp(-\frac{q}{kt} \cdot V_A)}$$

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

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

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

whose gain is :

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

Convert is into dB :

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

$ATT = 0dB$ when $V_A = 0$

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

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

and this shows that attenuation characteristic changes indexically for Vc 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 Vc provided is converted into control current Ic 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 Vc is added to the linear control terminal here.

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

$$V_{BE53} \fallingdotseq \frac{kt}{q} \ln \frac{I_{C53}}{I_S}$$

$$V_{BE58} \fallingdotseq \frac{kt}{q} \ln \frac{I_{C58}}{I_S}$$

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

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 :

$$I_{C53} = I_C = \frac{V_C}{R_{18}}$$

$$I_{C58} = I - I_{53} = I - \frac{V_C}{R_{18}}$$

and

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

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

$$\frac{V_o}{V_i} = \frac{2}{1 + \exp(-\frac{q}{kt} \cdot V_A)}$$

$$= \frac{2}{1 + \exp(-\frac{q}{kt} \cdot \frac{kt}{q} \ln \frac{I - (V_C/R_{18})}{V_C/R_{18}})}$$

$$= \frac{2}{I \cdot R_{18}} \cdot V_C$$

and excellent temperature characteristic and attenuation proportional to Vc 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.