M5206P

LINEAR CONTROL DUAL VCA IC

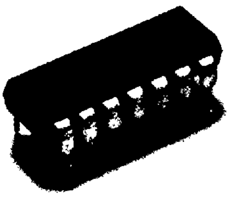
DESCRIPTION

The M5206P has 2 channels of built-in linear controlled VCA (Voltage controlled amplifier). These channels can be controlled independently.

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

FEATURES

- Contains 2 channels of VCAs and each of them has an built-in control pin.
- Linear control type VCA (attenuates proportionally to the control voltage with excellent linearity) ······ Vc = 5Vmax
- Large maximum input voltage ······ Vi = 8Vrms(THD = 1 %)
- Large ATT range ······ ATT = 0~ − 100dB
- Single power source and double-power source are both available COM terminal (Vcc/2 terminals are incorporated).
- High pressure proof ······ Vcc = ± 18V(36V)
- LOG control pin built-in as is with M5222 and M5241.



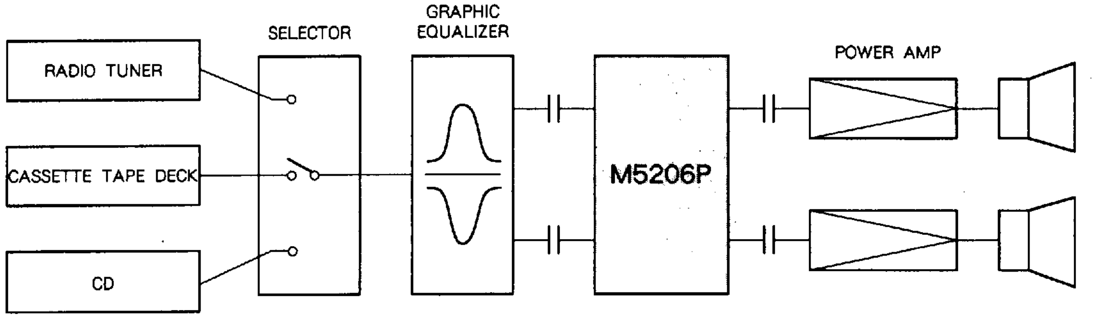
Outline 14P4

2.54mm pitch 300mil DIP
(6.3mm × 19.0mm × 3.3mm)

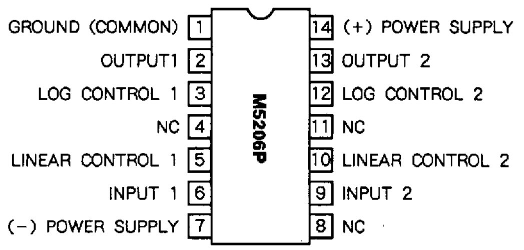
RECOMMENDED OPERATING CONDITIONS

Supply voltage range ······ Vcc, VEE = ± 7~± 16V
Rated supply voltage ······ Vcc, VEE = ± 15V
Linear control voltage range ······ LINE Vc = 0~5V
Log control voltage range ······ LOG Vc = 0V~350mV

SYSTEM CONFIGURATION



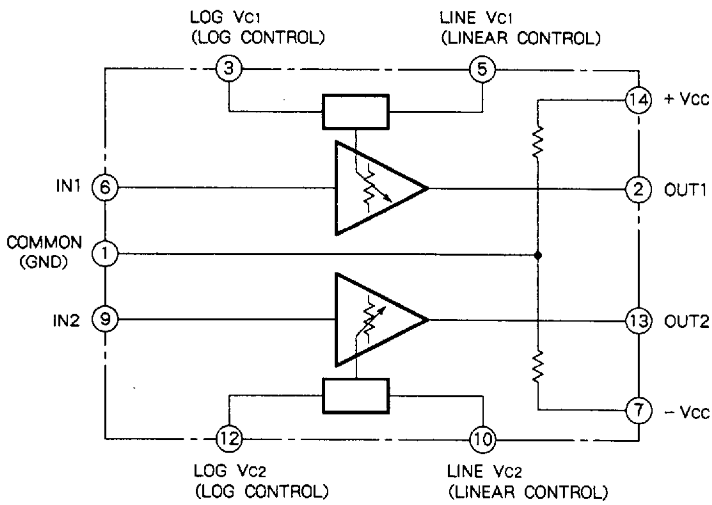
PIN CONFIGURATION



Outline 14P4

NC : NO CONNECTION

IC INTERNAL BLOCK DIAGRAM



PIN DESCRIPTION

Pin No.	Name	Symbol	Function
①	COM (GND)	COM (GND)	Vcc/2 is produced inside of the IC by resistive potential dividing and is supplied to pin①. Connect to GND when used by double-power sources. Use it as a midpoint potential pin when used by the single power source.
②	Ch1 output	OUT1	This is an output pin on ch1 side. Input signals from ch1 input pin is output to this pin as current signals.
③	Ch1 LOG control	Log V_{C1}	This is a Log control pin on ch1 side. Applying voltage (0V~350mV) between this pin and the COM pin will change the output logarithmically. About 100 nA of bias current is required.
④	Not connected	NC	This pin is not connected.
⑤	Ch1 linear control	LINE V_{C1}	This is a linear control pin on ch1 side. Applying DC voltage (0V~5V) between this pin and the COM pin will change the output linearly. About 100 nA of bias current is required.
⑥	Ch1 input	IN1	This is an input pin on ch1 side. Input is converted into current signals by input resistor R_1 to be input to this pin.
⑦	(−) power	−Vcc	This is a power pin on minus side. This has the lowest potential in this IC.
⑧	Not connected	NC	This is the power pin on plus side.
⑨	Ch2 input	IN2	This is an input pin on ch2 side. Input is converted into current signals by input resistor R_1 to be input to this pin.
⑩	Ch2 linear control	LINE V_{C2}	This is a linear control pin on ch2 side. Applying DC voltage (0V~5V) between this pin and the COM pin will change the output linearly. About 100 nA of bias current is required.
⑪	Not connected	NC	This pin is not connected
⑫	Ch2 LOG control	Log V_{C2}	This is a Log control pin on ch2 side. Applying voltage (0V~350mV) between this pin and the COM pin will change the output logarithmically. About 100 nA of bias current is required.
⑬	Ch2 output	OUT2	This is an output pin on ch2 side. Input signals from ch2 input pin is output to this pin as current signals.
⑭	(+) supply voltage	+Vcc	This is the power pin on plus side.

ABSOLUTE MAXIMUM RATINGS (Ta = 25℃, unless otherwise noted)

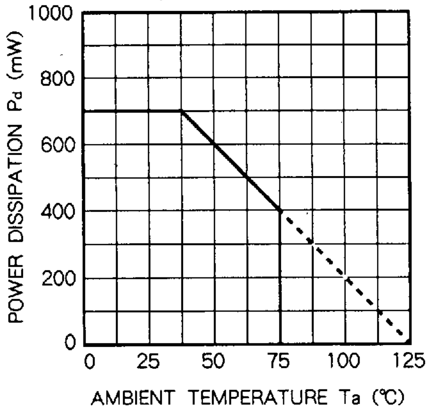
Symbol	Parameter	Ratings	Unit
V_{CC}	Supply voltage	±18 (36)	V
P_d	Power dissipation	700	mW
K_θ	Thermal derating	7	mW/℃
T_{opr}	Operating temperature	−20~+75	℃
T_{stg}	Storage temperature	−55~+125	℃

ELECTRICAL CHARACTERISTICS (Ta = 25℃, V_{CC} = ± 15V, $V_{C\ (LINE)}$ = 5V, $V_{C\ (LOG)}$ = 0V, unless otherwise noted)

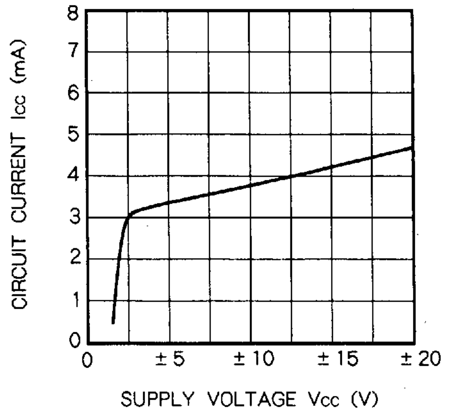
Symbol	Parameter	Test conditions	Limits Min	Limits Typ	Limits Max	Unit
I_{CC}	Circuit current	V_i = 0V	–	4.3	7.5	mA
V_{IM}	Maximum input voltage	f = 1kHz, THD = 1 %	5.6	8.0	–	Vrms
I_{OO}	Output offset current	V_i = 0V	–	± 0.3	± 2.0	μ A
Δ ATT1	Attenuation error	f = 1kHz, V_i = + 10dBm	– 1.0	0.5	2.0	dB
Δ ATT2	Attenuation deviation between channels	f = 1kHz, V_i = + 10dBm	–	± 0.3	± 2.0	dB
ATT1	Logarithm maximum attenuation	f = 1kHz, V_i = + 10dBm, $V_{C\ (LOG)}$ = 350mV	–	– 100	– 85	dB
ATT2	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~30kHz	–	70	–	dB
HR	Hum rejection	f = 120Hz	–	57	–	dB
V_{NO}	Output noise voltage	V_i = 0V, BW : 10Hz~30kHz	–	60	120	μ Vrms

TYPICAL CHARACTERISTICS

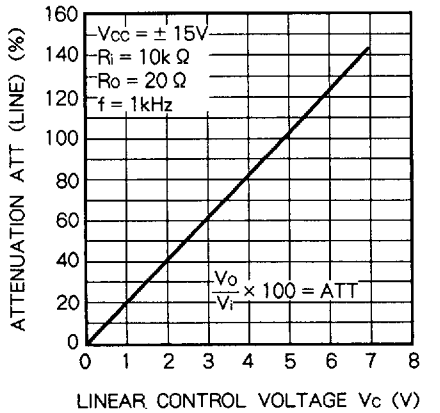
THERMAL DERATING (MAXIMUM RATING)



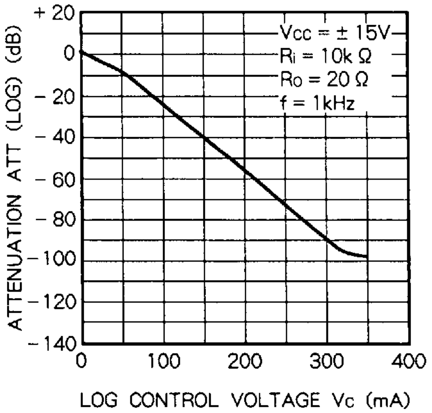
CIRCUIT CURRENT VS. SUPPLY VOLTAGE



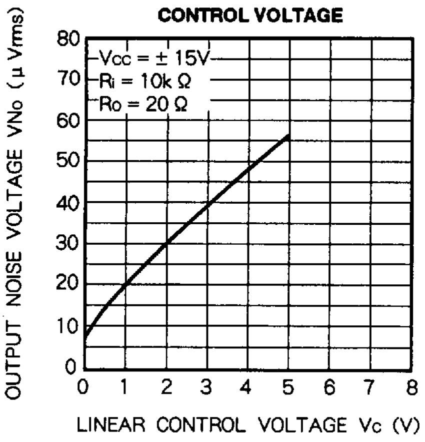
ATTENUATION VS. CONTROL VOLTAGE



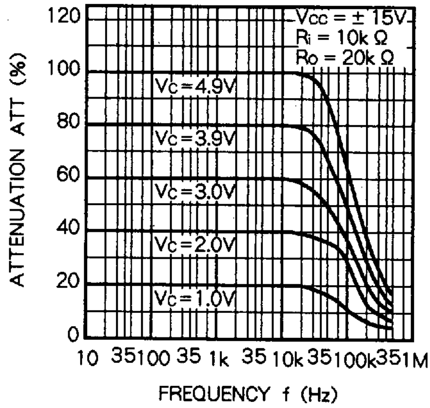
ATTENUATION VS. CONTROL VOLTAGE



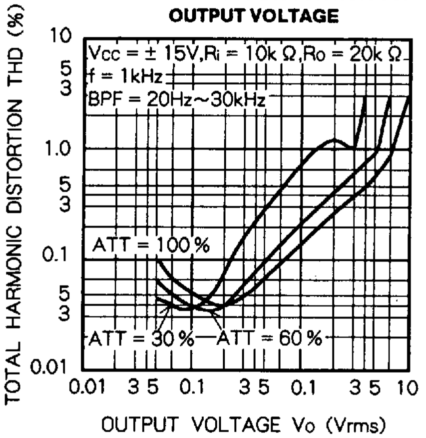
OUTPUT NOISE VOLTAGE VS. CONTROL VOLTAGE



ATTENUATION VS. FREQUENCY

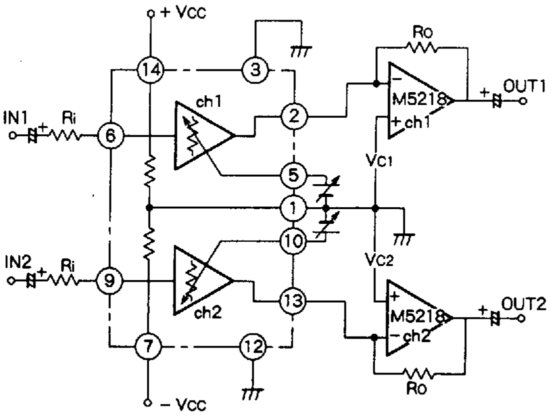


TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE

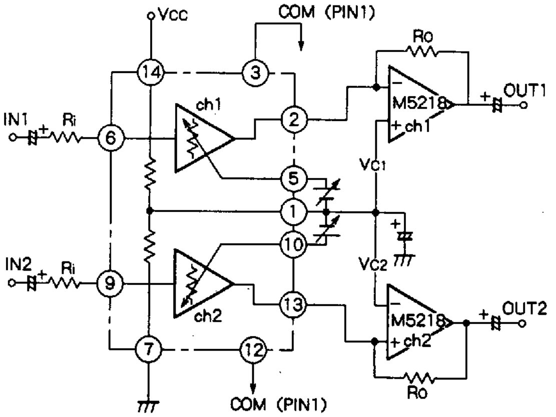


APPLICATION EXAMPLE

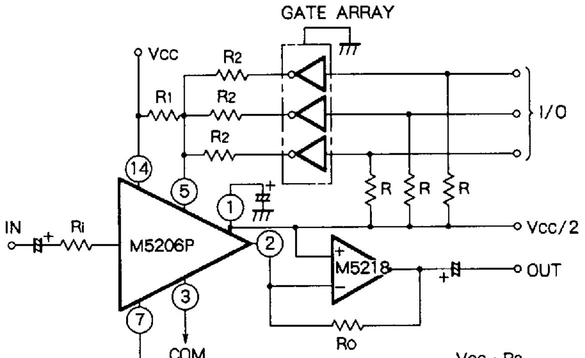
Standard application example



(a) Double power source is used.



(b) Single power source is used.

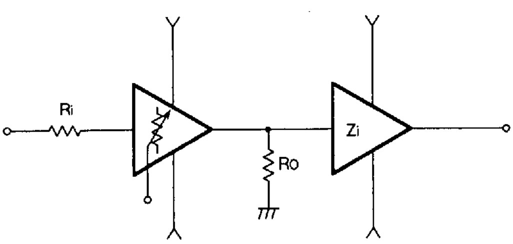


$* \ Vc = \frac{Vcc \cdot R_2}{R_1 + R_2}$

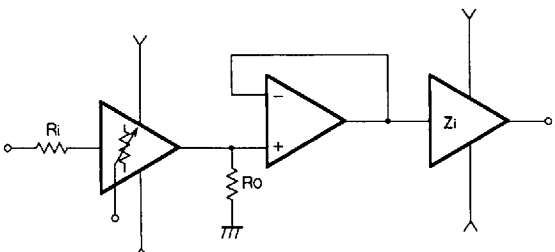
* R IS A PULL-UP RESISTOR

NOTES

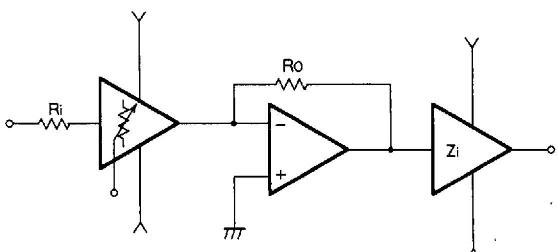
1. Selecting $R_O = 2R_i$ will valance the internal differential circuit (when $V_{C\ LINE} = 5V$ and $V_{C\ LOG} = 0V$), providing 0dB of one time amplifier.
2. Output circuit is a float output type based on collector connections of transistors PNP and NPN, and it is requred to set the potential at one end of external resistor Ro. (See the "Mechanism of I/O Voltage and Current Conversion" section.)
3. M5206P uses amplifiers of class A and class B for the "voltage ↔ current" conversion. Unlike M5222 and M5241, the maximum input current value is not determined by its limit value, however, there exists a maximum value because of the saturation of output transistor. Therefore, to input large signals select larger input/output resistances and decrease the input current.
   Since using larger resistance will increase the noise, select some proper resistance value according to the use of the IC.
4. The voltage gain is determined by Vc, R_i, and Ro so that it may be affected by the value of input impedance connected to the next. (Z_i is inserted in parallel with Ro to decrease the impedance.) (See following figure)



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



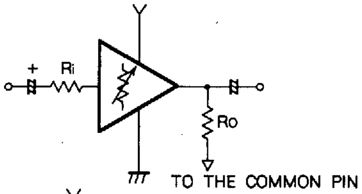
(a)

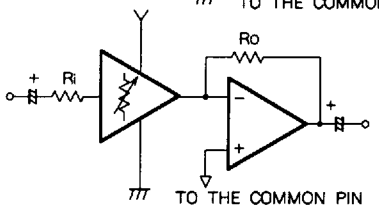


(b)

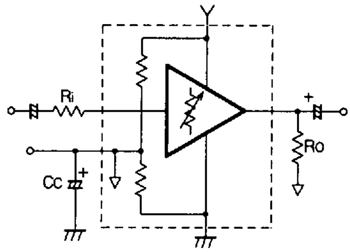
Note the following differences. In the circuit in Figure (a), its input signal has the antiphase, the potential of the output pin may be changed by the signals, and the maximum output voltage is also affected by the residual voltage in the output circuit. (About 1V of residual voltage will be generated form the + Vcc as well as the − Vcc.) In the circuit in Figure (b), any input signal has the equal phase, the potential of the output pin is fixed, and the residual voltage in the output circuit does not have any influence.

5. Cautions when using the single power supply :
   - Set the one end voltage of the Ro to COMMON potential.

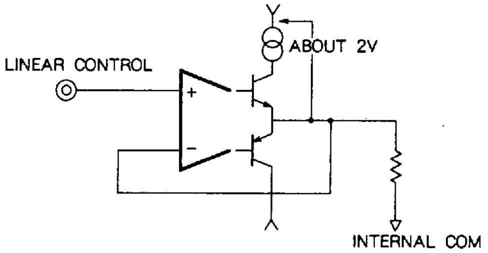




   - Connect a capacitor Cc between the COMMON pin and the Ground to decrease the impedance of the COM pin.

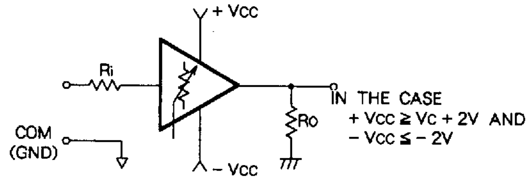


6. The range of supply voltage is widely affected by the range of the control voltage. A stage of current mirror circuit is connected to the output push-pull circuit of the control circuit to that at least 2V of residual voltage from the Vcc is needed ($V_{CC} \geq V_C + 2V$). At least 2V is needed for the $-V_{CC}$ operation.

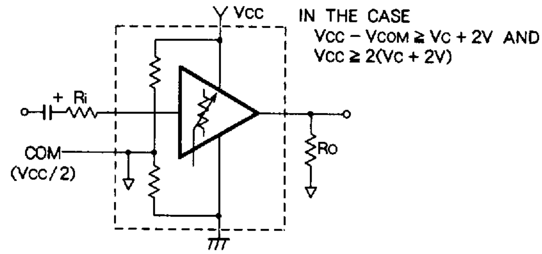


This IC contains a midpoint voltage generator. If the single power source is used, set ($V_{CC} - V_{COM}$) becomes larger than ($V_C + 2V$).(V_{COM} is usually $V_{CC}/2V$).

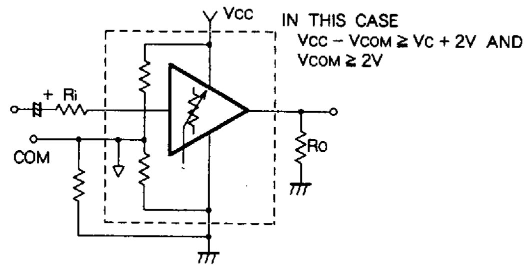
At least 2V of potential V_{COM} is needed between the ground and the COM pin for proper operation. To make the value of the Vcc small, use an external resistor for shifting the level of the V_{COM}.



(a) When the double-power source is used :

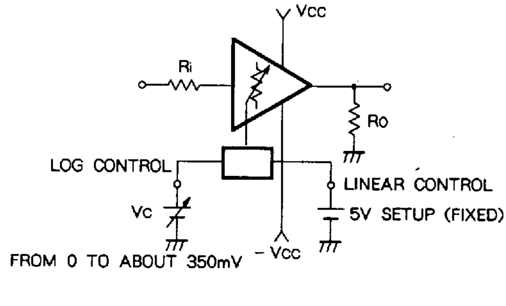


(b) When the single-power source is used :
(without any change)



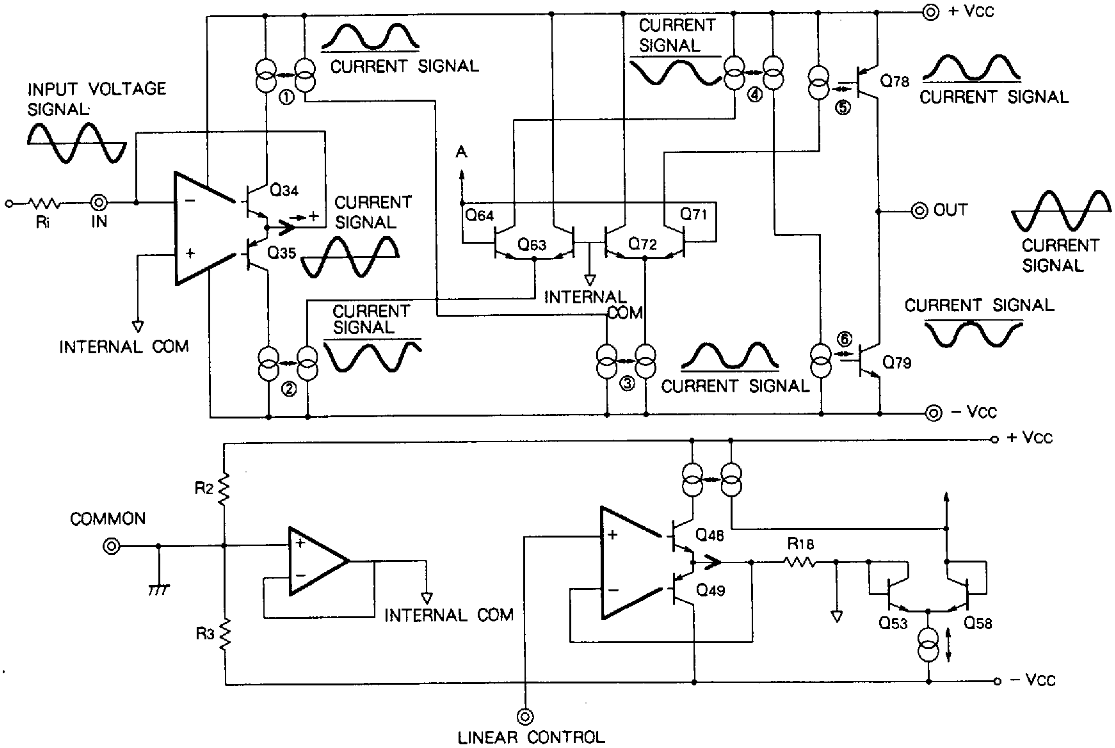
(c) When the single-power source is used
(V_{COM} level is sifted) :

7. In case of using the LOG control of the M5206P, logarithmical attenuation, as that in M5222 and M5241, can be done because of the existence of the LOG control pin in this IC.
   Following figure shows the connection of this case. The control of the attenuation is done by supplying the puls voltage Vc to the COMMON pin. Supply 5V to the linear control pin.(5V is the required condition for obtaining the 0dB of attenuation by the liner control voltage.)



8. To obtain the attenuation chracteristics using the linear control pin of M5206P, the LOG control pin should be shorted with the COM pin or it should be biased by the COM pin potential.

OPERATION CIRCUIT



BASIC OPERATION PRINCIPLES

M5206P is a VCA (Voltage Controlled Amplifier) IC which accepts and outputs electric current. This converts input signals to current signals using an external resistor and sends them to the current mirror output circuit through a differential circuit. These current signals are converted again to voltage signals by an external output resistor, therefore, it works as if a voltage I/O device. The attenuation is controlled by the control voltage Vc while changing the balance (changing the gm) in the differential circuit.

The following describes the basic operation of the IC.

1. Mechanism of I/O voltage and current conversions

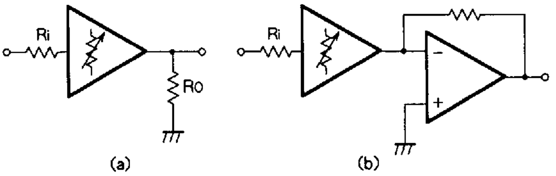
As shown in the block diagram, the input circuit is a voltage / current conversion circuit with operational amplifier configration. By connecting an external input resistor R_I, the input voltage V_i is supplied to the inside of the IC as the input current i_i $(=V_i/R_I)$. (The phase will be reversed.)

The current sent is divided into half waves by the push-pull circuit (Q_{34} and Q_{35}) in the input operational amplifier and they are sent as the current signals to the output circuit by current mirrors ① to ⑥ and differential circuits (Q_{63}, Q_{64}, Q_{71}, and Q_{72}).

The output circuit forms a current composition circuit with the current mirror configuration. Resulting (composed) current signals can be obtained from the output pin.

These current signals can be obtained as output signals Vo using the external output resistor.

It is required to set some proper DC electric potential at one end of the output resistor because the output circuit has the float output type due to the collector connection of PNP and NPN transistors.



As shown in the above figure, there are two methods for the setup :

(1) Set the one end of the Ro pin to the equal potential to COM (GMD when the double-power source is used).

(2) Use a current/voltage conversion circuit based on an operational amplifier.

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

2. Attenuation mechanism

The output control is done by supplying positive voltage to the Vc pin of the COM pin.

The gain of this circuit is changed by changing the current distribution for the differential circuit, which can be done by giving a fixed potential from the COM pin to one of the base (Q_{63}, Q_{72}) of the differential circuit and giving the control voltage Vc to another base (Q_{64}, Q_{71}) through the control circuit.

If the external control voltage is directly supplied to the base (Q_{64}, Q_{71}), the characteristics of the attenuation versus control voltage will change logarithmically as explained below, however, it will be changed to the linear caracteristics by inserting a control circuit.

This is one of the major features of the IC.

(1) Basic mechanism of the attenuation

Input signal V_i is converted to the current signal i_i = $(=V_i/R)$ by the input resistor R_i.

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

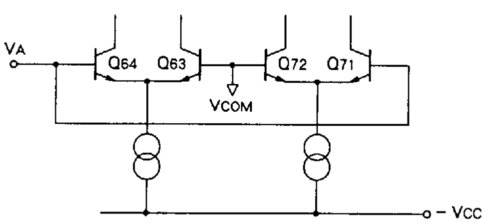
When the differential circuit is balanced (base potentials are equal), collector current in Q_{63} and Q_{64}, Q_{71} and Q_{72} become eual and the current sent by current mirrors ① to ③ is divided equally at this point. This current is sent to the output pin by current mirrors ④ to ⑥, half-waves are composed, 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 us observe the attenuation characteristics with this resistor selection where the COM potential is provided to the base for Q_{63} and Q_{72} and V_A to the base for Q_{64} and Q_{71}. The current signal having been divided into half waves by the push-pull circuit is shown as i_{i+} and i_{i-}.($i_i = i_{i+} + i_{i-}$)



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

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

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

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

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

k : Bolztman's constant
T : Absolute temperature
q : Electric charge
Is : Saturation current

The above equations result in the following :

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

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

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

Here, equations below are valid,

$$I_{C63} + I_{C64} = I_{i-}$$

$$I_{C71} + I_{C72} = I_{i+}$$

Therefore,

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

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

When the double-power source is used, $V_{COM} = 0V$.
For simplicity, it is noted as $V_{COM} = 0$.
As a result, the following equations are obtained :

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

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

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

Thus, the current shown in the following equation flows into the output pin :

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

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

Its again will be as follows :

$$\frac{V_o}{V_i} = \frac{i_o \cdot R_o}{I_i \cdot R_i} = \frac{i_o \cdot 2R_i}{I_i \cdot R_i}$$

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

Now, convert this into dB :

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

and when $V_A = 0$, ATT = 0dB.

Also, when $1 \ll \exp\left(-\frac{q}{kt} \cdot V_A\right)$

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

showing the attenuation changes logarithmically for the Vc change.

(2) Linear control mechanism

As explained above, the attenuation changes logarithmically for the potential difference of base in the differential circuit. However, by supplying control voltage through the linear control circuit, the attenuation fot the control voltage can change linearly.

The control circuit consists of an operational amplifier, current mirrors, and differential circuits, as indicated in the block diagram.

As first, supplied control voltage Vc is converted into the control current Ic by R_{18}.

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

Differential circuits Q_{53} and Q_{58} are biased by the constant current I and when

$$I_{C53} = I_{C58} = \frac{1}{2}$$

the differential circuits are balanced. (When $V_C = 5V$)

That is the potential V_A at the point A will be equal to that of V_{COM}.

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

Remembering of the previous section, the attenuation becomes 1dB or one time of gain. Suppose the control voltage Vc is supplied to the linear control pin.

Each value for V_{BE} will be as follows :

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

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

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

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

When the double-power source is used, $V_{COM} = 0$.
For simplicity, it is noted as $V_{COM} = 0$.

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

Since I_{C53} and I_{C58} are as follows,

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

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

and

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

If the substitutes the equation for the gain obtained before, the following equation is given :

$$\frac{V_O}{V_I} = \frac{2}{1 + \exp\left(-\frac{q}{kt} \cdot V_A\right)}$$

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

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

Thus, you may have an excellent temperature characteristics as well as the attenuation which is proportional to the Vc change.

This control circuit also as has the compensation function when the amount of attenuation is not enough (i. e. the gain does not become 0 when $V_C = 0$) due to the offset voltage of differential circuits.