MITSUBISHI SOUND PROCESSOR ICs

M5241L

DUAL VCA FOR ELECTRONIC VOLUME CONTROL

DESCRIPTION

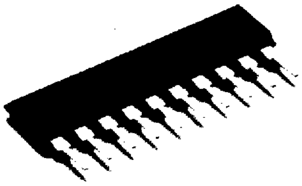
The M5241L is an optimum logarithmic VCA for controlling the volume of analog audio signals.

Each channel has a control pin and capable of independent operation.

The IC can be used in radio cassette tape recorders, car audio systems, and Hi-Fi VCR.

FEATURES

- Independent control terminal is provided 2 channels of VCA are incorporated
  ………… ch1 and ch2 can be controlled separately by Vc control (pin⑥, ⑦)
- Maximum input voltage is large
  ………………………………V_i = 3Vrms(when THD = 0.5%)
- Low distortion……………THD = 0.02%(when V_o = 1Vrms)
- Large ATT range…………………………………0 to −100dB
- S/N(dynamic range) is large……………………………… 94dB
  (when ATT = 0dB, R_i = 15kΩ, R_o = 30kΩ, R_c = 1.8kΩ)
- Logarithmic response VCA
  ……………………………… Logarithmic response equivalent to A-curve volume control
- Bias current controllable can be adjusted with external resistor
- Can be operated with a single power supply
  ………………………… Built-in COM pin③ Vcc/2 bias pin



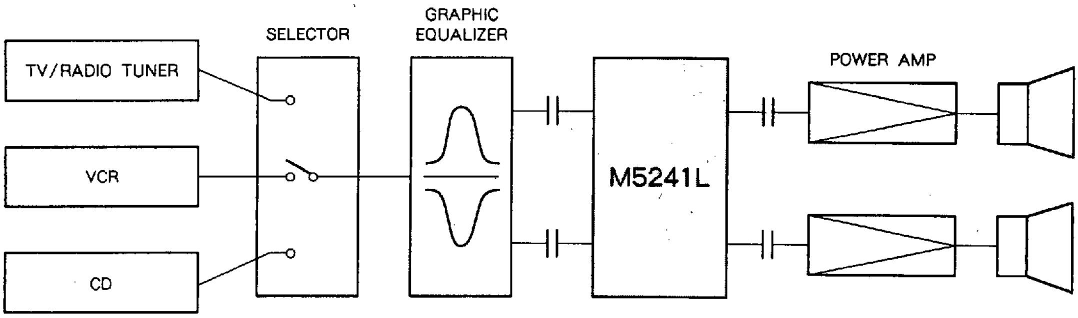
Outline 10P5

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

RECOMMENDED OPERATING CONDITIONS

Supply voltage range…………………… V_{CC}, V_{EE} = ± 7 to ± 18V

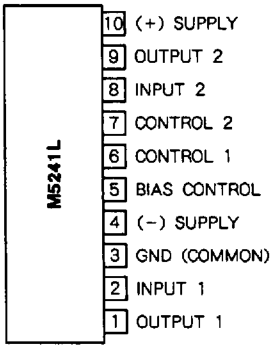
SYSTEM CONFIGURATION



M5241L

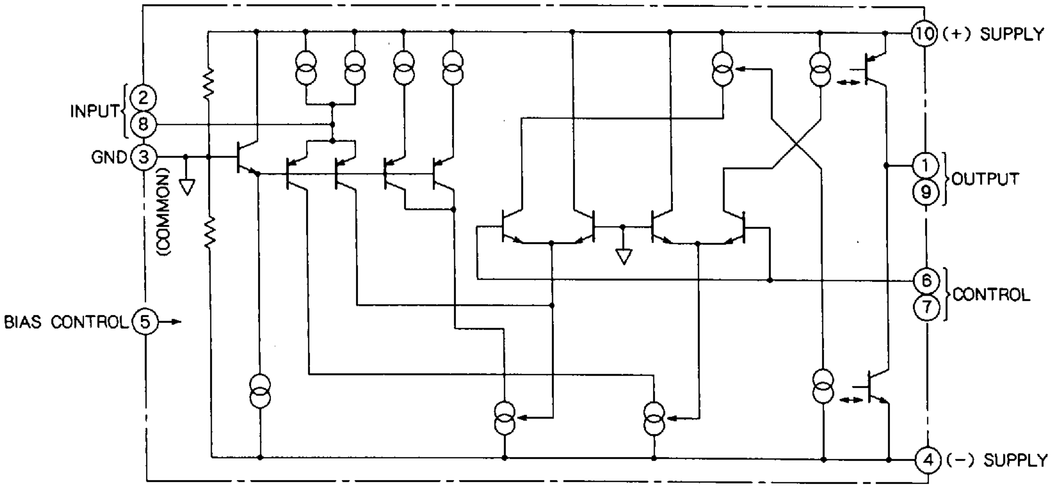
DUAL VCA FOR ELECTRONIC VOLUME CONTROL

PIN CONFIGURATION (TOP VIEW)



Outline 10P5

IC INTERNAL BLOCK DIAGRAM



MITSUBISHI ELECTRIC

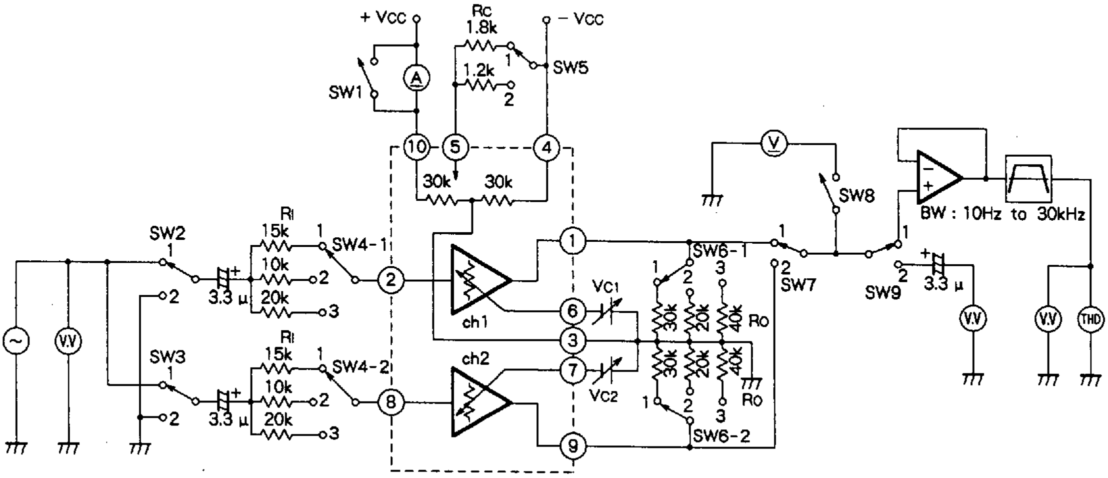
ABSOLUTE MAXIMUM RATINGS (Ta = 25℃, unless otherwise noted)

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=±15V, Ri=15kΩ, Ro=30kΩ, Rc=1.8kΩ, Vc=0V unless otherwise noted)

Symbol	Parameter	Test conditions		Limits			Unit
				Min	Typ	Max	
I_{CC}	Circuit current	V_i = 0V		2.5	3.8	6.5	mA
V_{IM1}	Maximum input voltage		f = 1kHz THD = 0.5 %	2.4	3.0	–	Vrms
V_{IM2}		R_i = 20k Ω, R_o = 40kΩ		–	4.2	–	Vrms
V_{IM3}		R_i = 10k Ω, R_o = 20kΩ, R_c = 1.2k Ω		–	2.5	–	Vrms
ATT_M	Maximum attenuation	V_i = + 10dBm, f = 1kHz, Vc = − 300mV		–	− 102	− 85	dB
ATT	Attenuation error	V_i = + 10dBm, f = 1kHz		− 2.0	− 0.5	+ 3.0	dB
Δ ATT	Attenuation deviation between channels	V_i = + 10dBm, f = 1kHz		–	± 0.1	± 3.0	dB
I_{OO}	Output offset current	V_i = 0V		–	± 5	± 20	μ A
THD1	Total harmonic distortion	ATT = 0dB (Vc=0), V_o=1Vrms	f = 1kHz, filter BW:10Hz to 30kHz	–	0.02	0.1	%
THD2		ATT=-10dB (Vc=-43mV), V_i=1Vrms		–	0.04	–	%
THD3		ATT=-20dB (Vc=-76mV), V_i=1Vrms		–	0.06	–	%
CS	Channel separation	f = 1kHz		–	73	–	dB
HR	Hum rejection	f = 120Hz		–	48	–	dB
V_{NO1}	Noise output voltage	ATT = 0dB (Vc = 0)	BW:10Hz to 30kHz	–	57	120	μVrms
V_{NO2}		ATT=-40dB (Vc=-138mV)		–	8.5	–	μVrms
V_{NO3}		ATT=0dB (Vc=0), Vo=1Vrms, Ro=20kΩ, Rc=1.2kΩ		–	38	–	μVrms

TEST CIRCUIT

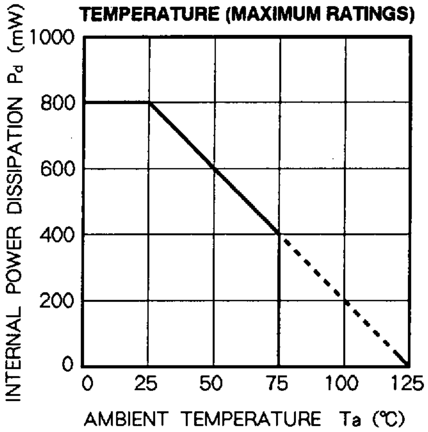


SWITCH MATRIX

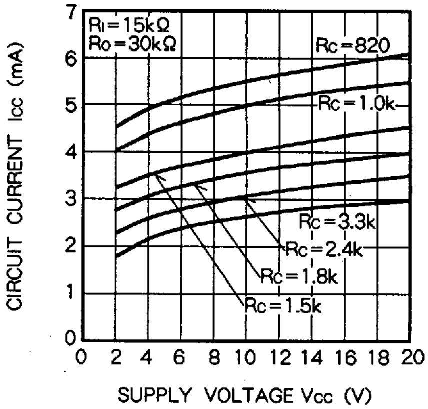
Parameter		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	$V_{C1,2}$
Circuit current	I_{CC}	OFF	2	2	1	1	1	–	OFF	2	0V
Maximum input voltage	V_{IM1}	ON	1	1	1	1	1	1/2	OFF	1	0V
	V_{IM2}	ON	1	1	3	1	3	1/2	OFF	1	0V
	V_{IM3}	ON	1	1	2	2	2	1/2	OFF	1	0V
Maximum attenuation	ATT_M	ON	1/2	2/1	1	1	1	1/2	OFF	2	−300mV
Attenuation error	ATT	ON	1	1	1	1	1	1/2	OFF	2	0V
Attenuation diviation	Δ ATT	ON	1	1	1	1	1	1/2	OFF	2	0V
Output offset current	I_{OO}	ON	2	2	1	1	1	1/2	ON	2	0V
Total harmonic distortion	THD_1	ON	1/2	2/1	1	1	1	1/2	OFF	1	0V
	THD_2	ON	1/2	2/1	1	1	1	1/2	OFF	1	−43mV
	THD_3	ON	1/2	2/1	1	1	1	1/2	OFF	1	−76mV
Noise output voltage	V_{NO1}	ON	2	2	1	1	1	1/2	OFF	1	0V
	V_{NO2}	ON	2	2	1	1	1	1/2	OFF	1	−138mV
	V_{NO3}	ON	2	2	2	2	2	1/2	OFF	1	0V
Channel separation	C.S	ON	2/1	1/2	1	1	1	1/2	OFF	2	0V

TYPICAL CHARACTERISTICS

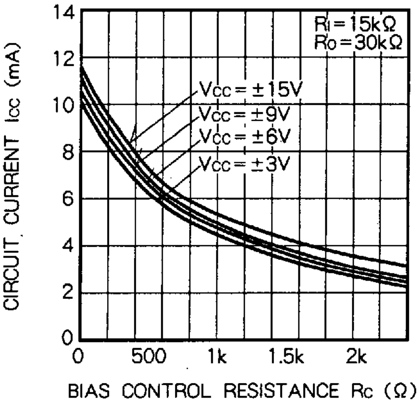
POWER DISSIPATION VS. AMBIENT TEMPERATURE (MAXIMUM RATINGS)



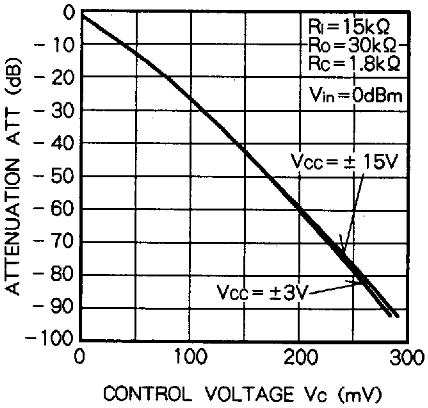
CIRCUIT CURRENT VS. SUPPLY VOLTAGE



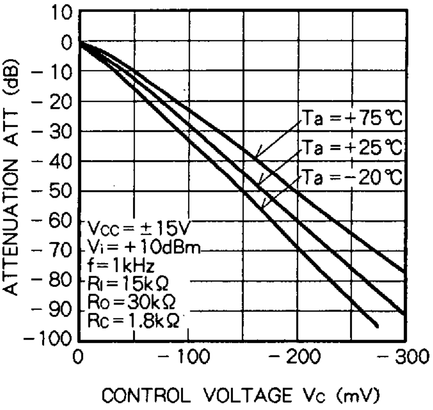
CIRCUIT CURRENT VS. BIAS CONTROL RESISTANCE



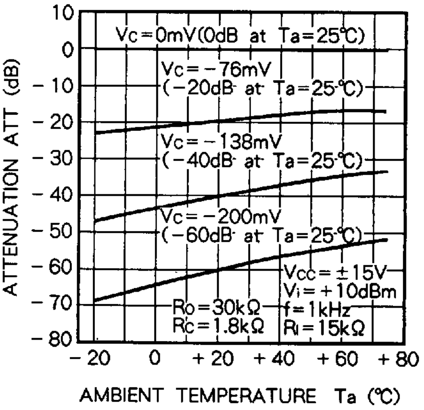
ATTENUATION VS. CONTROL VOLTAGE



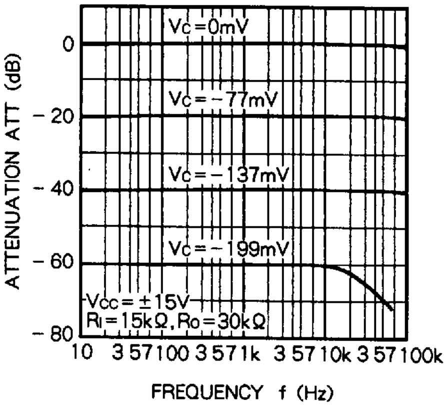
ATTENUATION VS. CONTROL VOLTAGE



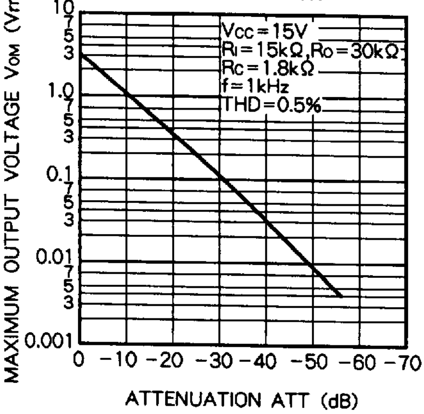
ATTENUATION VS. AMBIENT TEMPERATURE



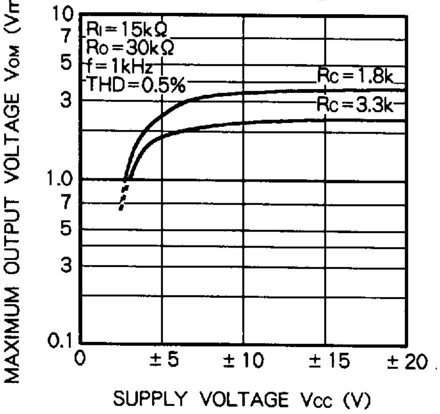
ATTENUATION VS. OUTPUT VOLTAGE



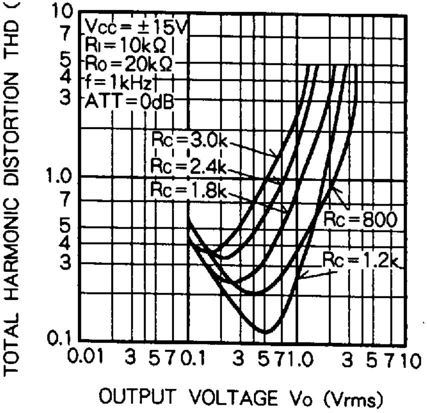
MAXIMUM OUTPUT VOLTAGE VS. ATTENUATION



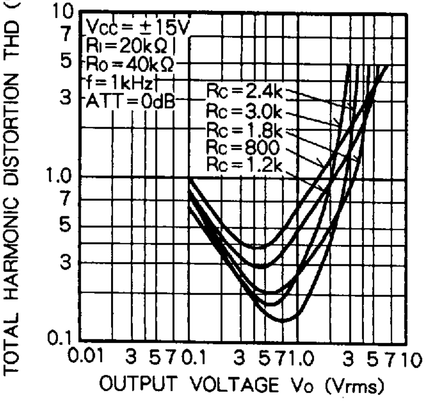
MAXIMUM OUTPUT VOLTAGE VS. SUPPLY VOLTAGE



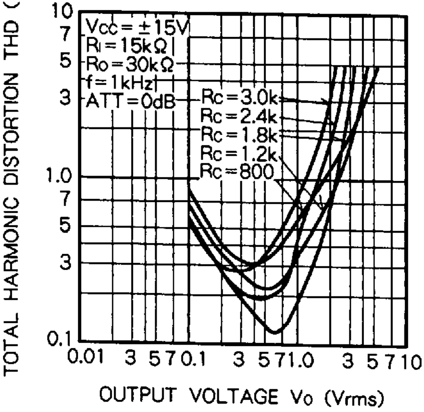
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



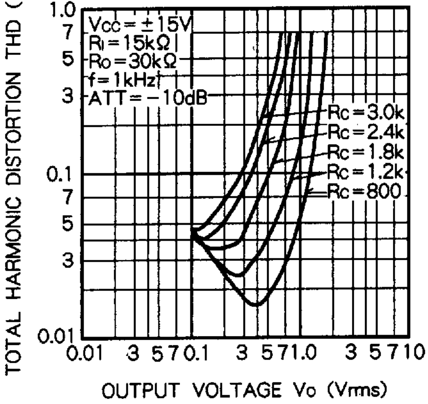
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



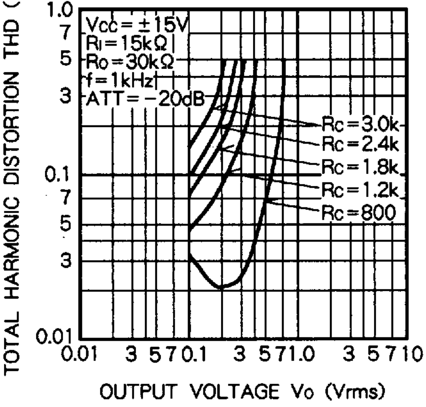
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



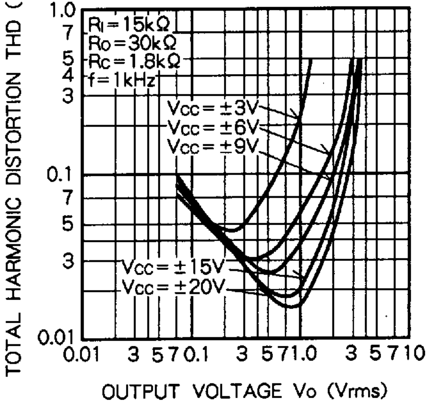
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



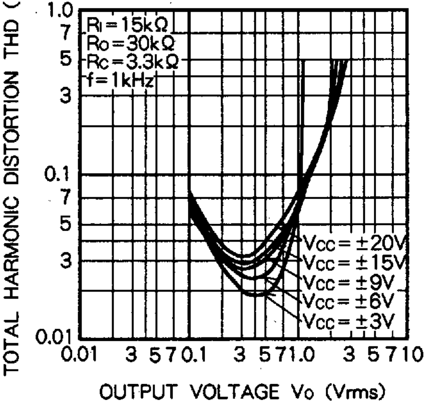
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



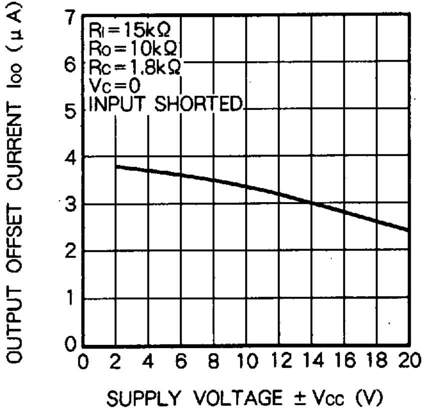
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



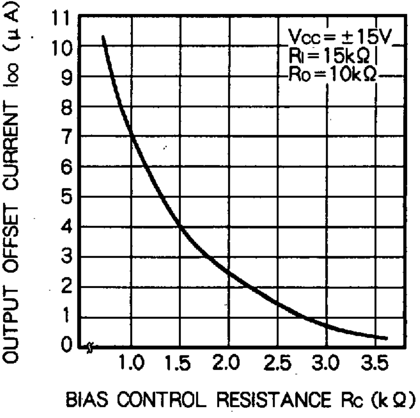
TOTAL HARMONIC DISTORTION VS. OUTPUT VOLTAGE



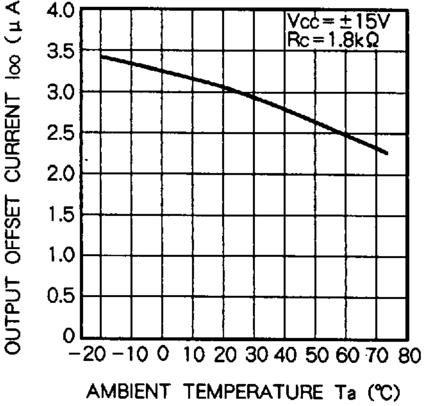
OUTPUT OFFSET CURRENT VS. SUPPLY VOLTAGE



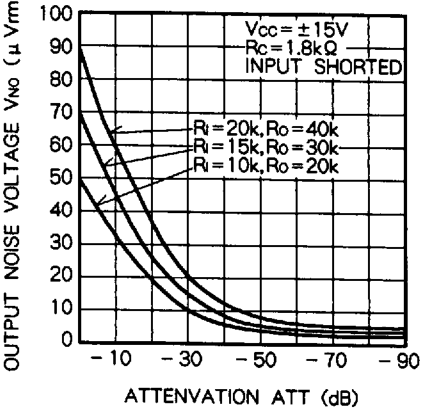
OUTPUT OFFSET CURRENT VS. BIAS CONTROL RESISTANCE



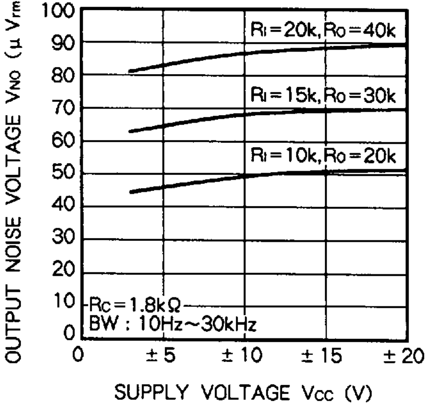
OUTPUT OFFSET CURRENT VS. AMBIENT TEMPERATURE



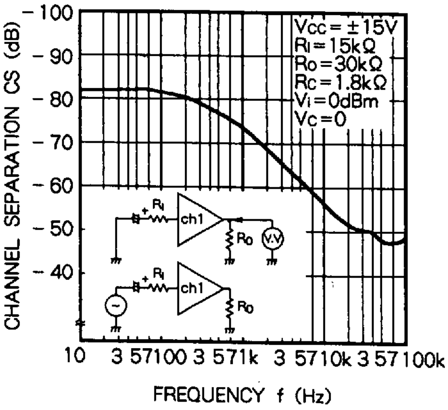
OUTPUT NOISE VOLTAGE VS. ATTENUATION



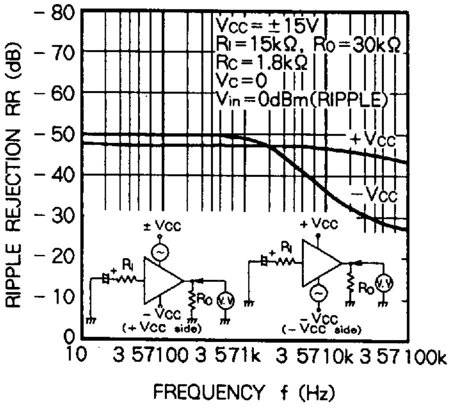
OUTPUT NOISE VOLTAGE VS. SUPPLY VOLTAGE



CHANNEL SEPARATION VS. FREQUENCY

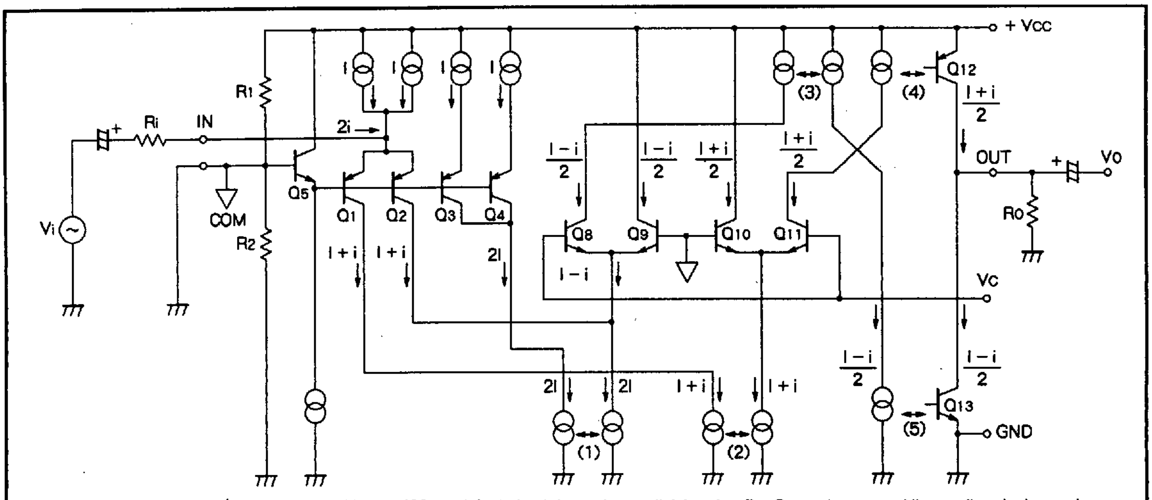


RIPPLE REJECTION VS. FREQUENCY



BASIC PRINCIPLE OF OPERATION

The M5241L is a current input, current output type of VCA IC. This amplifier uses the principle by which changing the balance of the differential circuit with external control voltage Vc will change gm. The circuit is also called a variable transconductance (variable gm) OP amp. The basic principle of operation will be simply explained below.



※ (⏚) is the Vcc/2 pin (COM pin) derived by voltage division by B_1, B2 and so on. All coupling is internal.

Fig. 1 M5241L Equivalent circuit

Basic voltage-current conversion mechanism for input and output

Applying the input signal V_i which flows through external input resistor R_i results in a change to a current signal at input terminal IN. The V_{BE} level shift of Q_1, Q_2 and Q_5 will cause input pin IN to become ground level. The signal input in this way will be sent to the output pin as a current signal by the current mirror and differential circuit. By taking this current through the externally-connected output resistor (load resistor), the signal can go through a current-to-voltage conversion and be obtained as output signal Vo. The output transistors combine the currents by means of the joined PNP and NPN collector circuits. Basically, the DC potential floats and is not determined in this joining of currents. This is why one end of externally-connected resistor Ro is connected to ground and the DC level at the time of no signal is set.

Basic mechanism of attenuation

The output is controlled by means of changing the control voltage applied to the Vc pin with respect to the COM pin (Vcc/2 pin). By applying voltage from the COM pin to the base of one side of a differential circuit and applying voltage from the Vc pin to the other base, the current distribution of the differential circuit is changed and the gain of this circuit is changed.

Let us first consider when Vc equals zero (Vc − COM is shorted). Input signal V_i is converted to current by input resistor R_i and the i currents ($2_i = V_i/R_i$) flow through the collectors of Q_1 and Q_2. When the current flowing in Q_i becomes I + i, the overall emitter current of the differential circuit consisting of Q_{10} and Q_{11} will also be determined as I + i by means of current mirror (2). Since the base potential of Q_{10} and Q_{11} is the same, the current will be divided equally and current (I + i) / 2 will flow in each of Q_{10} and Q_{11}. The current of current mirror (4) will also be determined as (I + i) / 2 because of this.

Since the current of current mirror (1) is determined as 2I by the current flowing in Q_3 and Q_4, the total of the current flowing in Q_2 and the current flowing in differential circuit Q_8, Q_9 will also be 2I. The current from Q_2 which will become I + i flows here and as a result, the overall emitter current of the differential circuit will be 2I − (I + i) = I − i. This current is devided the same way as in the differential circuit consisting of Q_{10} and Q_{11} with current (I − i) / 2 flowing in each of Q_8 and Q_9. From this, the current of current mirror (3) is determined as (I − i) / 2 and the current of current mirror (5) becomes (I + i) / 2.

Now, current (I − i) / 2 from current mirror (4) flows in transistor Q_{12} of the output stage. Since the current flowing in transistor Q_{13} from current mirror (5) is held at (I − i) / 2, connecting output resistor Ro between the output pin and the COM pin will result in current i flowing through Ro and providing a voltage signal Vo = i • Ro.

Here, by selecting Ro = 2R_i, Vo = i • Ro = 2_i • R_i = V_i and the amplifier will have a gain of 1.

Next, we will consider case of when control voltage Vc is applied with regard to the selection of this resistance.

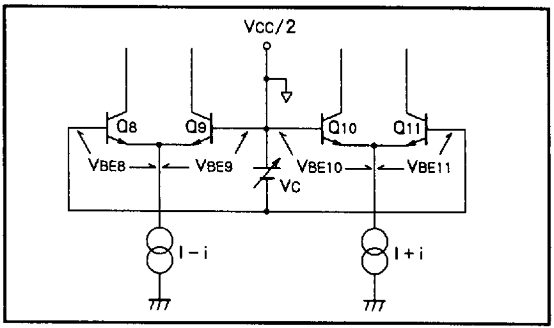


Fig. 2 Differential circuit

The values of V_{BE} of the differential stage will be as follows :

$$V_{BE8} \fallingdotseq \frac{kT}{q} \ln \left(\frac{I_{C8}}{I_S}\right)$$

$$V_{BE9} \fallingdotseq \frac{kT}{q} \ln \left(\frac{I_{C9}}{I_S}\right)$$

$$V_{BE10} \fallingdotseq \frac{kT}{q} \ln \left(\frac{I_{C10}}{I_S}\right)$$

$$V_{BE11} \fallingdotseq \frac{kT}{q} \ln \left(\frac{I_{C11}}{I_S}\right)$$

where,
- Is : the saturation current
- k : the Boltzmann constant
- q : the amount of electric charge on the electrons
- T : the absolute temperature

From this,

$$-V_C = V_{BE8} - V_{BE9} = \frac{kT}{q} \ln \left(\frac{I_{C8}}{I_{C9}}\right)$$

$$-V_C = V_{BE11} - V_{BE10} = \frac{kT}{q} \ln \left(\frac{I_{C11}}{I_{C10}}\right)$$

Here,

$$I_{C8} + I_{C9} \fallingdotseq I - i$$

$$I_{C10} + I_{C11} \fallingdotseq I + i$$

$$-V_C = \frac{kT}{q} \ln \frac{I_{C8}}{I - i - I_{C8}}$$

$$-V_C = \frac{kT}{q} \ln \frac{I_{C11}}{I + i - I_{C11}}$$

The current flowing through Q_8 and Q_{11} will be

$$I_{C8} = \frac{(I - i)\exp(-\frac{q}{kT}V_C)}{1 + \exp(-\frac{q}{kT}V_C)} = \frac{I - i}{1 + \exp(-\frac{q}{kT}V_C)}$$

$$I_{C11} = \frac{(I + i)\exp(-\frac{q}{kT}V_C)}{1 + \exp(-\frac{q}{kT}V_C)} = \frac{I + i}{1 + \exp(-\frac{q}{kT}V_C)}$$

Current I_{C11} is the current of current mirror (4), and I_{C8} will be the same as the current of current mirror (5).

At this time, the current that will flow through the output pin will be the same as that in the explanation when Vc was equal to zero, and is expressed as

$$i_o = \frac{2i}{1 + \exp(\frac{q}{kT} \cdot V_C)}$$

The gain will be

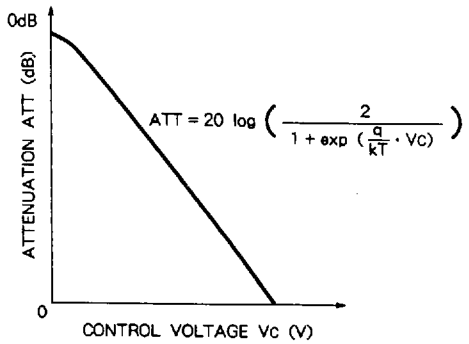
$$\frac{V_o}{V_i} = \frac{i_o \cdot R_o}{2i \cdot R_i} = \frac{2}{1 + \exp(\frac{q}{kT} \cdot V_C)}$$

and when calculated in dB,

$$ATT = 20 \log \left(\frac{2}{1 + \exp(\frac{q}{kT} \cdot V_C)}\right)$$

As in the graph below, the attenuation will change logarithmically with respect to the change of Vc.

ATTENUATION VS. CONTROL VOLTAGE



Setting and connection of input/output resistance

As explained above, the input signal is converted to current, but since the transistor of the input stage is biased at a fixed current ($I \fallingdotseq 170\,\mu A$ when $R_C = 1.8k\Omega$), the maximum value of the input current is determined at the least upper bound of I (Fig. 3). Accordingly, when a large signal is input, it is necessary to decrease the value of bias-control resistor Rc, select a large input/output resistance and decrease the input current. Note that decreasing the value of bias-control resistor Rc and increasing the input/output resistance will change the characteristic of the noise distortion factor, so set the values to suit the specific application.
(See characteristic curve)

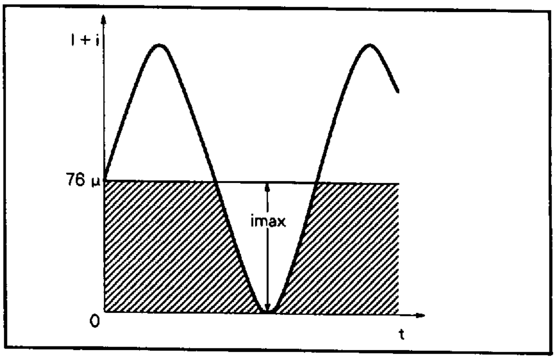


Fig. 3 Maximum current signal

Since the voltage gain (amount of attenuation) is determined by load resistor Ro through which the output current is taken, the value of the input impedance connected to the next stage is sometimes affected. (Placing Zi in parallel with Ro will lower the impedance.) Generally, a buffer amplifier composed of a transistor or OP amp is connected as shown in Fig. 4 (b).

The basic principle of operation on the 2-way power supply system has been explained thus far. Note that it is necessary to set COM pin (Vcc/2) to ground level by means of capacitor Co when a single power supply is used.

For operation on a single power supply, see the basic principle of operation for M5222. For connection, see application examples.

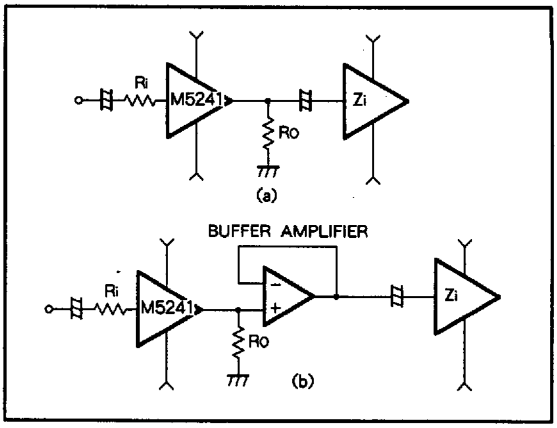
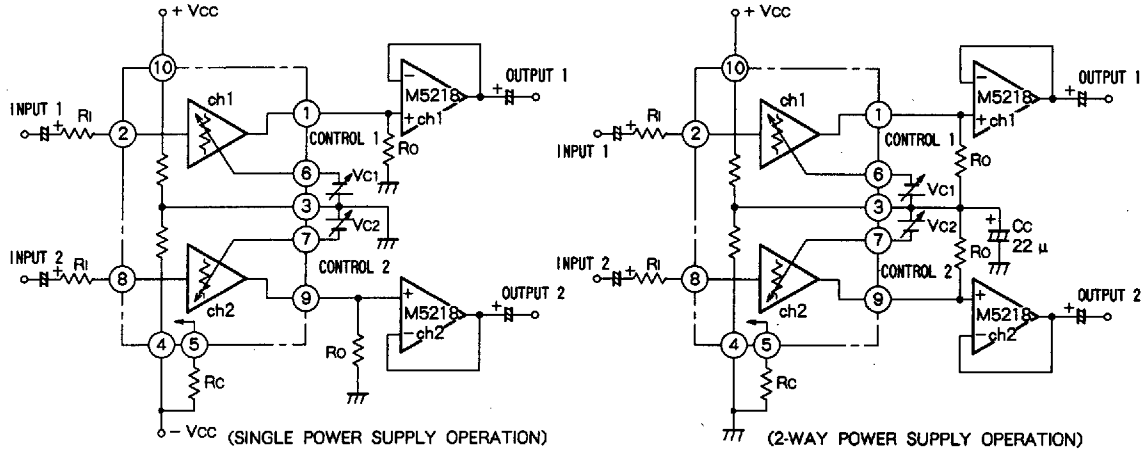


Fig. 4 Connection example

APPLICATION CIRCUIT

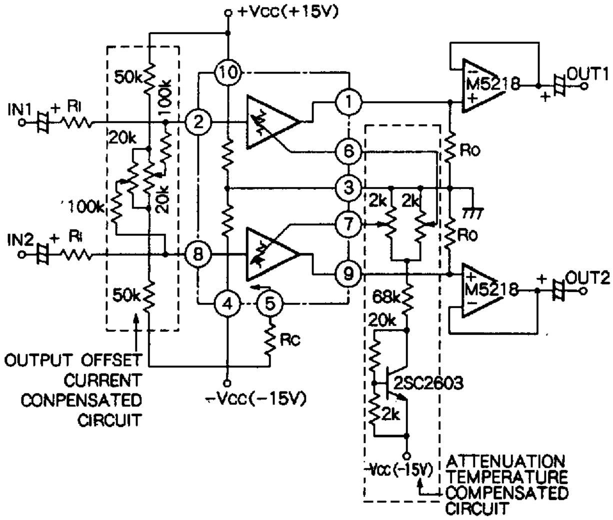
(1) TYPICAL APPLICATION EXAMPLE



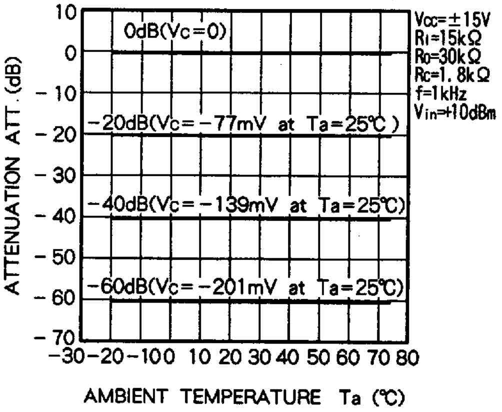
(SINGLE POWER SUPPLY OPERATION) (2-WAY POWER SUPPLY OPERATION)

* When Vc = 0V, attenuation of 0dB is obtained by selecting Ro = 2Ri.

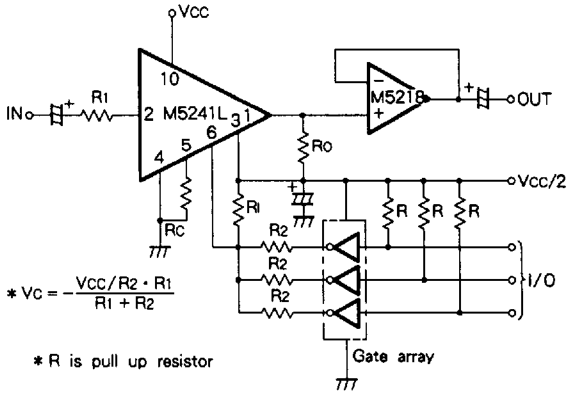
(2) TEMPERATURE COMPENSATED, OUTPUT OFFSET COMPESATED CIRCUITS



ATTENUATION VS. AMBIENT TEMPERATURE (TEMPERATURE COMPENSATED)



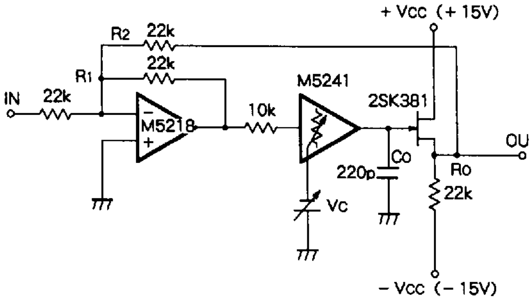
PROGRAMMABLE ATTENUATION CIRCUIT



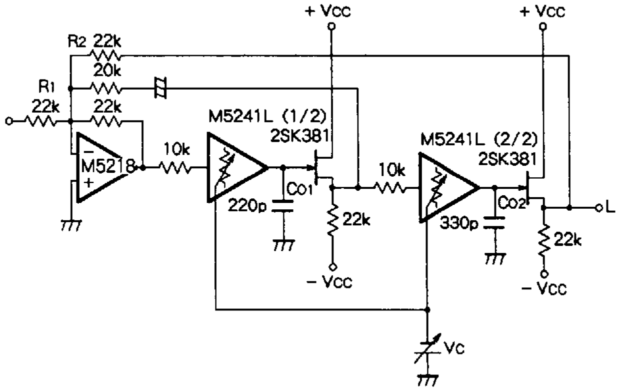
$*\,V_C = -\frac{V_{CC}/R_2 \cdot R_1}{R_1 + R_2}$

* R is pull up resistor

VCF(FIRST-ORDER LOW-PASS FILTER)

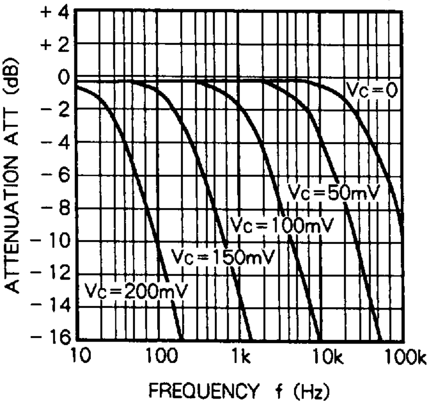


VCF(SECOND-ORDER LOW-PASS FILTER)



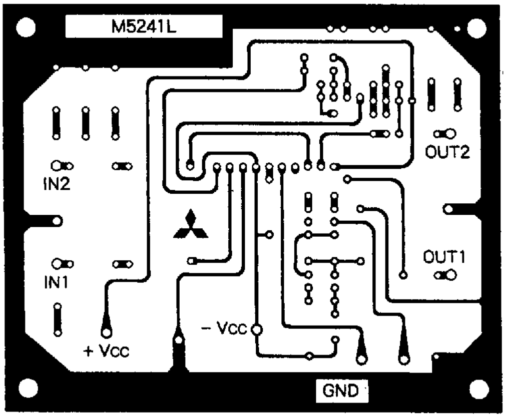
Units Resistance : Ω
Capacitance : F

ATTENUATION VS. FREQUENCY RESPONSE (FIRST-ORDER LOW-PASS FILTER)



PRINTED CIRCUIT BOARD FOR CIRCUIT TESTING

PC BOARD PARTS-PLACEMENT DIAGRAM (COPPER FOIL SIDE)



PC BOARD PARTS-PLACEMENT DIAGRAM (PARTS SIDE)