M5222L/P/FP

DUAL VCA FOR LOW VOLTAGE ELECTRONIC VOLUME CONTROL

DESCRIPTION

The M5222 is a dual VCA designed as an electronic volume control capable of operating in a wide supply voltage range between 1.8V to 20V.

The IC is an optimum device for electronic equipment requiring low voltage operation, such as video movie systems.

FEATURES

- Capable of operating at low voltage·····Vcc = 1.8 to 20V
- Two built-in channels ······················Simultaneous control of both channels is possible with Vc(control) at pin ⑤
- Logarithmic response VCA ······ Logarithmic response equivalent to A-curve volume
- Large ATT range························ 0dB(Vc ≒ 0) to −90dB (Vc ≒ −270mV)(typ)
- High maximum input voltage ································Vi = 1.0Vrms(typ)(@ Vcc = 3V)
- Low distortion ratio··································THD = 0.05 %
- Similar characteristics between 2 channels

Outline 8P5(L)

2.54mm pitch 340mil SIP
(2.8mm × 19.0mm × 6.4mm)

Outline 8P4(P)

2.54mm pitch 300mil DIP
(6.3mm × 8.9mm × 3.3mm)

RECOMMENDED OPERATING CONDITIONS

Supply voltage range······························Vcc = 1.8 to 20V

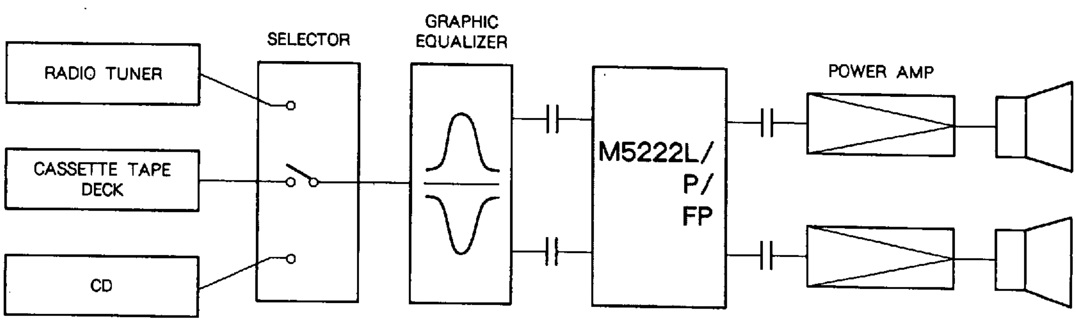
Rated dissipation voltage

································· 800(L), 625(P), 440(FP)mW

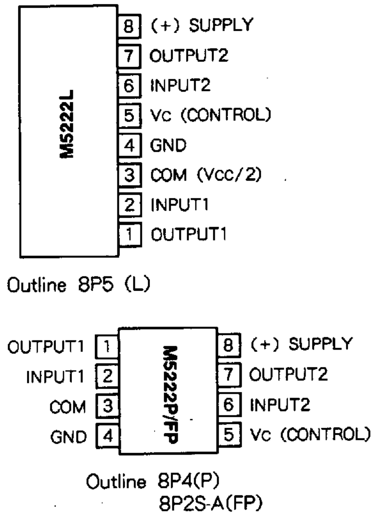
Outline 8P2S-A(FP)

1.27mm pitch 225mil SOP
(4.4mm × 5.0mm × 1.5mm)

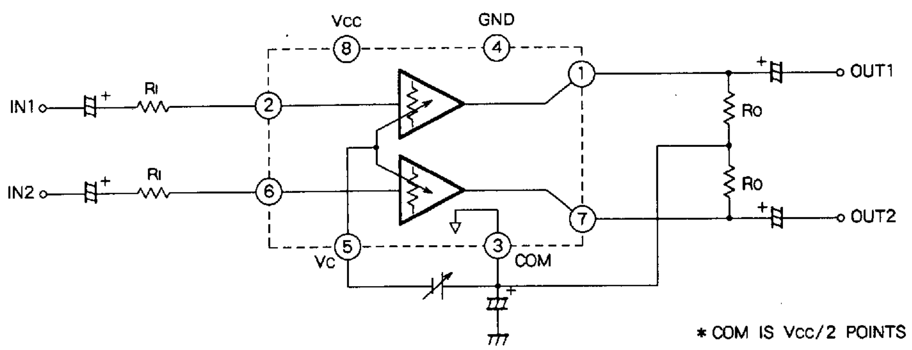
SYSTEM CONFIGURATION



PIN CONFIGURATION (TOP VIEW)



IC INTERNAL BLOCK DIAGRAM



Note 1. RI is used to convert input voltage to current.
2. Ro is an output resistor used to convert the currentoutput signal to voltage. Connect this output with COM pin 3 to fix the DC output potential.
3. The COM pin is used for making a 1/2pint supply voltage within the IC. It is used in connecting Ro and in Vc control.

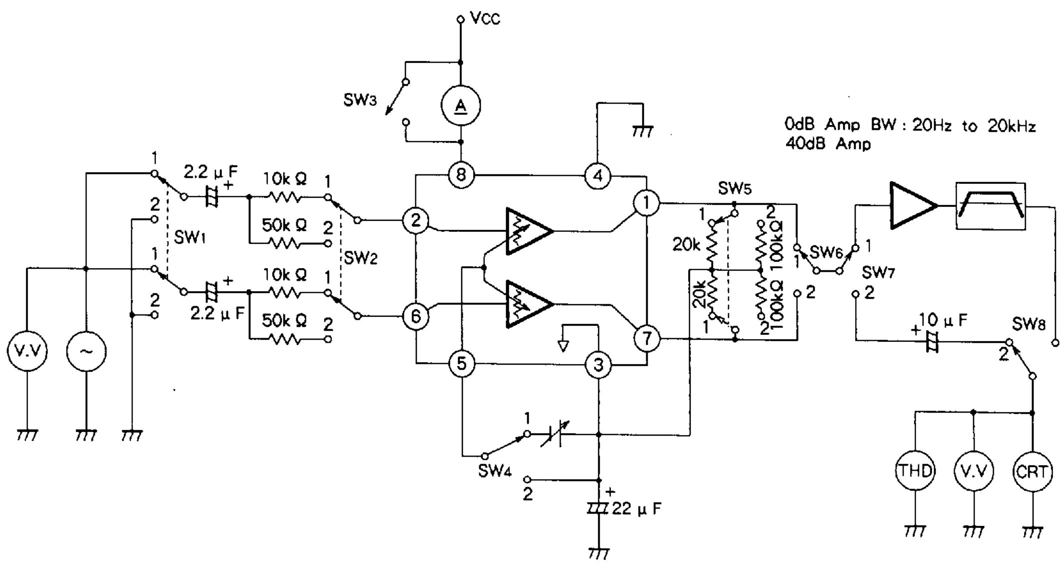
ABSOLUTE MAXIMUM RATINGS (Ta = 25℃, unless otherwise noted)

Symbol	Parameter	Ratings	Unit
Vcc	Supply voltage	20	V
P_d	Power dissipation	800(SIP)/625(DIP)/440(FP)	mW
K_θ	Thermal derating (Ta ≧ 25℃)	8(SIP)/6.25(DIP)/4.4(FP)	mW/℃
T_{opr}	Operating temperature	−20 to +75	℃
T_{stg}	Storage temperature	−55 to +125	℃

ELECTRICAL CHARACTERISTICS (Ta = 25℃, unless otherwise noted)

Symbol	Parameter	Test conditions		Limits			Unit
			Vcc	Min	Typ	Max	
Icc	Circuit current	V_i = 0, V_C = 0	3V	2.5	3.6	5.5	mA
V_iM1	Maximum input voltage	f = 1kHz, V_C = 0, THD = 1%; R_I = 10kΩ, R_O = 20kΩ	3V	0.7	1.0	−	Vrms
V_iM2	Maximum input voltage	f = 1kHz, V_C = 0, THD = 1%; R_I = 50kΩ, R_O = 100kΩ	9V	2.3	3.4	−	Vrms
ATT_M	Maximum attenuation	R_I = 10kΩ, R_O = 20kΩ, V_C = −270mV	3V	80	90	−	dB
ATT_{01}	Attenuation error	f = 1kHz, V_C = 0, V_i = 0dBm; R_I = 10kΩ, R_O = 20kΩ	3V	−4.4	−1.4	+1.6	dB
ATT_{02}	Attenuation error	f = 1kHz, V_C = 0, V_i = 0dBm; R_I = 50kΩ, R_O = 100kΩ	9V	−5.0	−2.0	+1.0	dB
Δ ATT	Attenuation deviation between channels	f = 1kHz, V_C = 0, V_i = 0dBm, R_I = 10kΩ, R_O = 20kΩ	3V	−	0.1	3.0	dB
V_{NO1}	Noise output voltage	V_C = 0, R_I = 10kΩ, R_O = 20kΩ, BW = 20Hz to 20kHz	3V	−	30	60	μVrms
V_{NO2}	Noise output voltage	ATT = −40dB, R_I = 10kΩ, R_O = 20kΩ, BW = 20Hz to 20kHz	3V	−	5	−	μVrms

TEST CIRCUIT

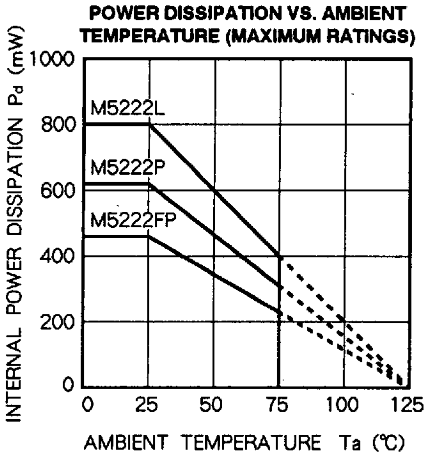


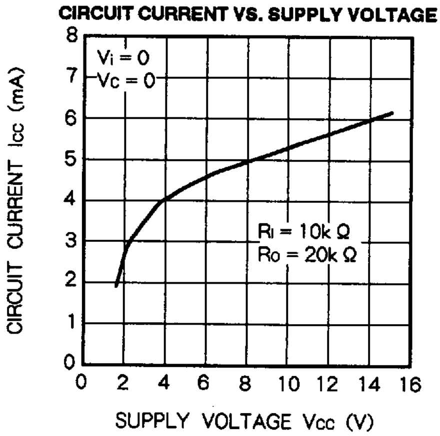
SWITCH MATRIX

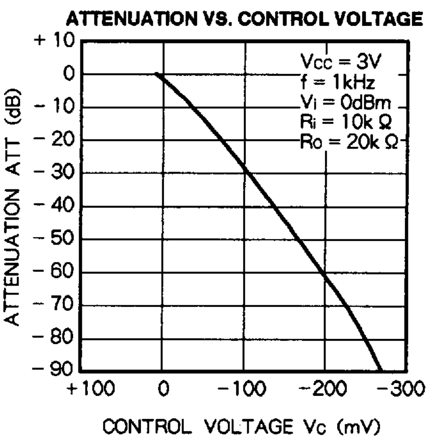
Parameter		SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8
Icc		2	1	OFF	2	1	1/2	2	2
V_{IM}	1	1	1	ON	2	1	1/2	1	1
	2	1	2	ON	2	2	1/2	1	1
ATTM		1	1	ON	1	1	1/2	2	2
ATT	01	1	1	ON	2	1	1/2	2	2
	02	1	2	ON	2	2	1/2	2	2
V_{NO}	1	2	1	ON	2	1	1/2	1	1
	2	2	1	ON	1	1	1/2	1	1

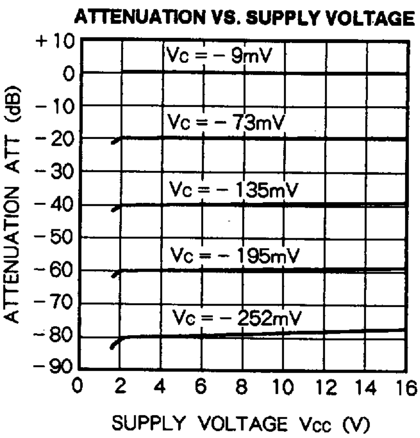
Note 1. Use 0dB amplification when measuring VIM
2. Use 40dB amplification when measuring VNO
3. VNO = measurement value/100 (40dB) [μ Vrms]

TYPICAL CHARACTERISTICS

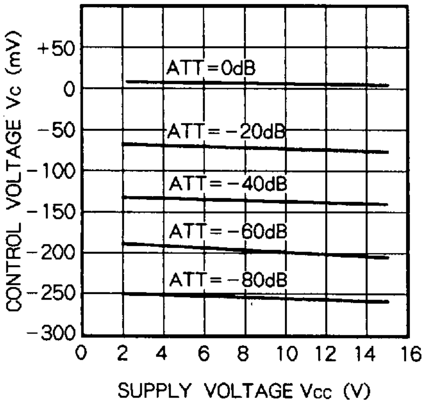




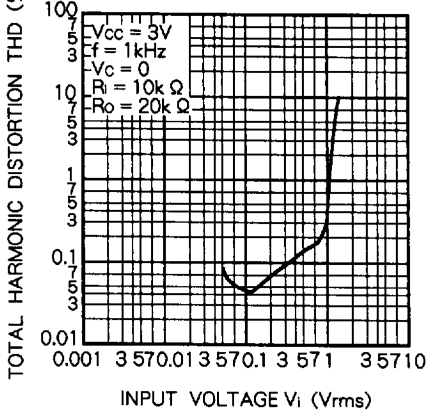




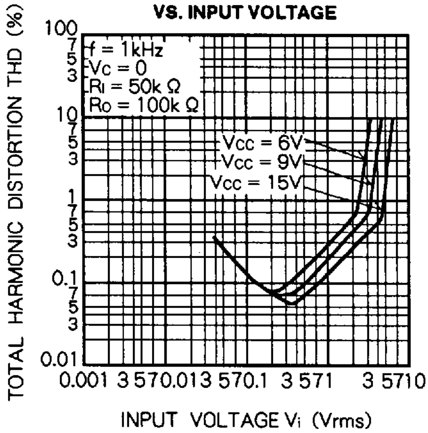
CONTROL VOLTAGE VS. SUPPLY VOLTAGE



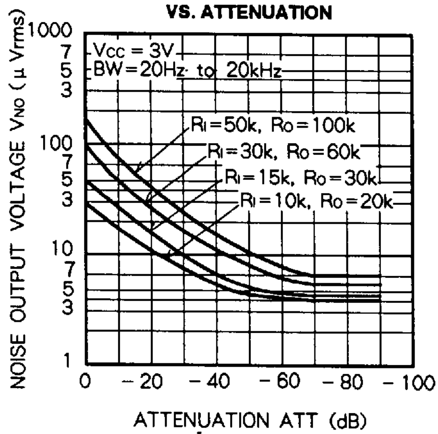
TOTAL HARMONIC DISTORTION VS. INPUT VOLTAGE



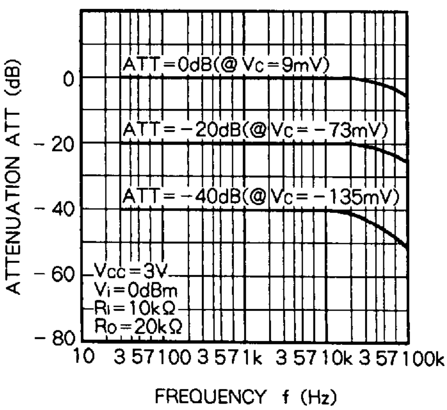
TOTAL HARMONIC DISTORTION VS. INPUT VOLTAGE



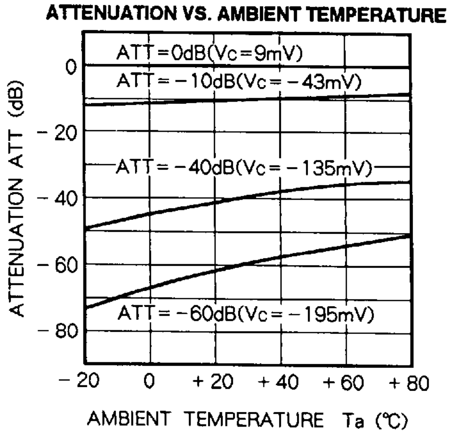
NOISE OUTPUT VOLTAGE VS. ATTENUATION



ATTENUATION VS. FREQUENCY

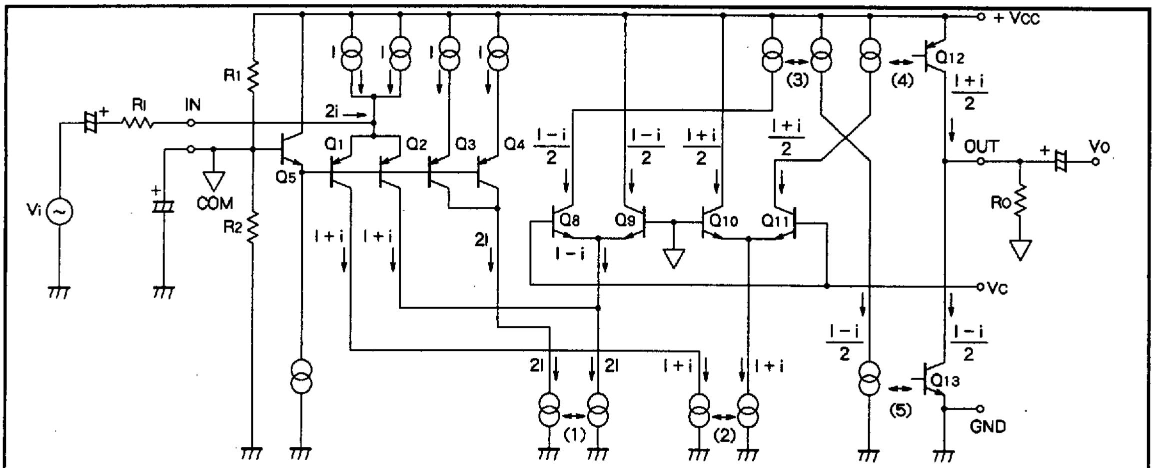


ATTENUATION VS. AMBIENT TEMPERATURE



BASIC PRINCIPLE OF OPERATION

The M5222 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 B1, B2 and so on. ALL coupling is internal.

Fig. 1 M5222 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 R_1, R_2, Q_5, Q_1, and Q_2 will cause input pin IN to become ground level by means of Vcc/2 in terms of direct current and to become ground level by means of the externally-connected capacitor in terms of alternating current. 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 signal 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 the Vcc/2 pin and the DC level (Vcc/2) 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 ($2i = V_i/R_i$) 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 $V_o = i \cdot R_o$.

Here, by selecting $R_o = 2R_i$, $V_o = i \cdot R_o = 2i \cdot R_i = V_i$ 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.

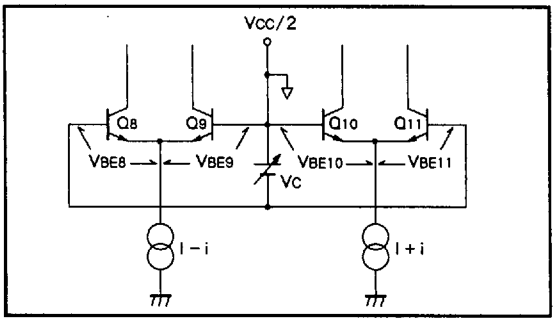


Fig. 2 Differential circuit

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, (I_S : the saturation current
k : the Boltzmann constant
q : the amount of electric charge on the electrons
T : the absolute temperature)

From this,

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

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

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

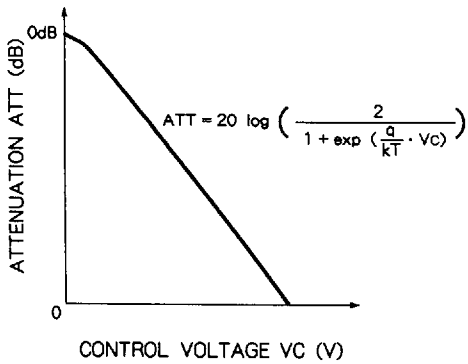
$$\frac{V_O}{V_i} = \frac{i_O \cdot R_O}{2_i \cdot R_I} = \frac{2}{1 + \exp(\frac{q}{kT} \cdot V_C)}$$

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 of $I = 76\,\mu A$, 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 select a large input/output resistance and decrease the input current. Note that increasing the resistance will also increase the noise distortion factor, so the value of the setting should be made to suit the particular application.

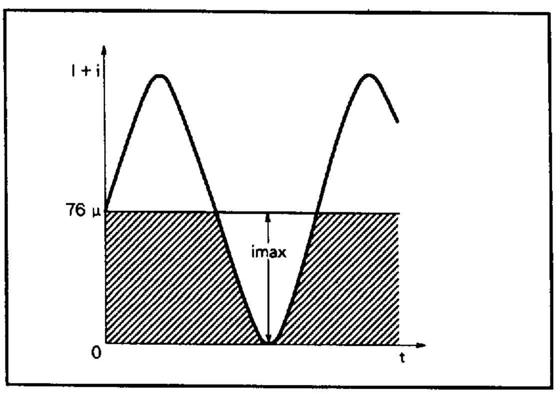


Fig. 3 Maximum current signal

The M5222 has a floating-type output stage with the collectors of Q_{12} and Q_{13} joined as shown in FIG. 4. Here, the difference of the combined currents will become the output current that will flow through the load. Note that it is necessary to set the DC potential of this output pin by externally-connected resistor Ro and that it is generally DC-connected to the Vcc/2 pin (or to pin (3)).

In terms of AC, it is necessary to set the output pin to ground level so that capacitor C is required. Since the voltage gain (amount of attenuation) is determined by Ro, the value of the input impedance connected to the next stage is sometimes affected. (Placing Z_I in parallel with Ro will lower the impedance.) Generally, a buffer amplifier composed of a transistor or OP amp connected.

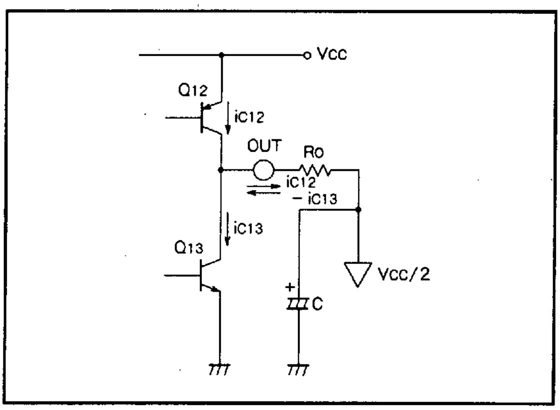


Fig. 4 Equivalent circuit of output stage

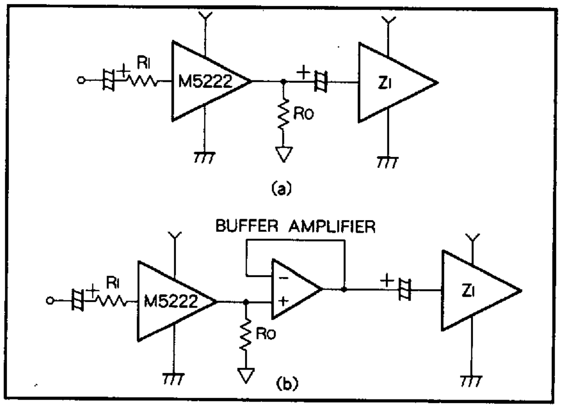
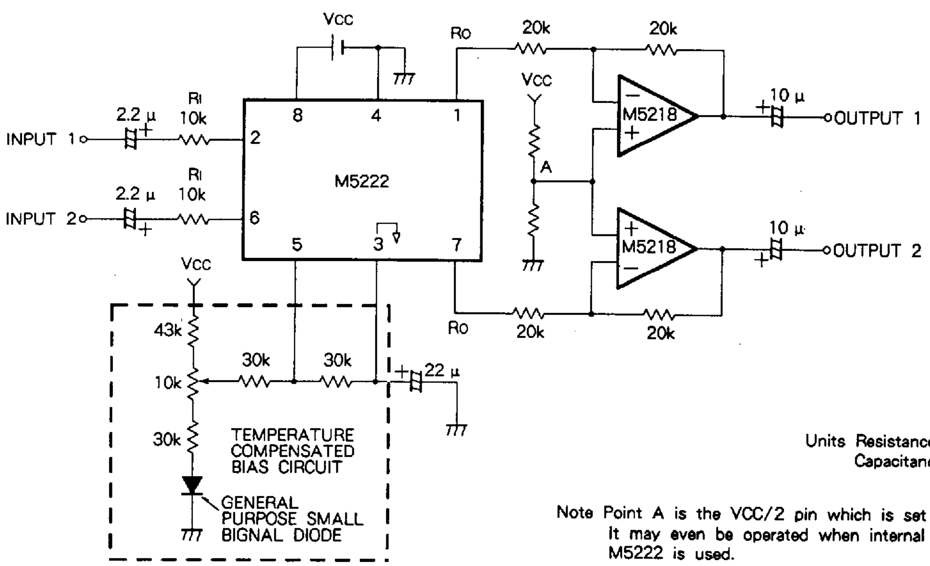


Fig. 5 Connection example

APPLICATION EXAMPLES

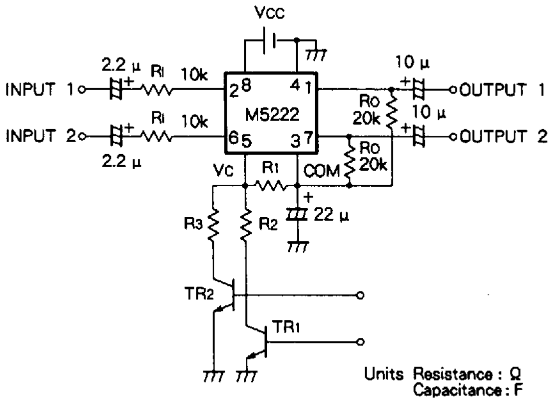
(1) TEMPERATURE COMPENSATED BIAS AND OUTPUT BUFFER CIRCUITS



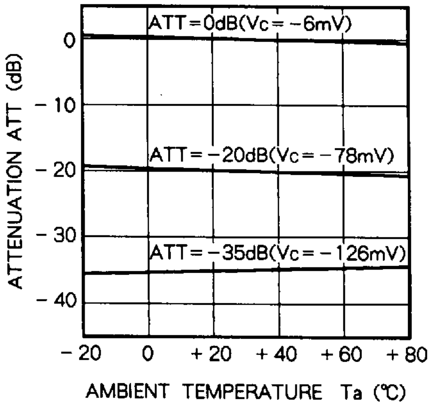
Units Resistance : Ω
Capacitance : F

Note Point A is the VCC/2 pin which is set externally. It may even be operated when internal pin 3 of M5222 is used.

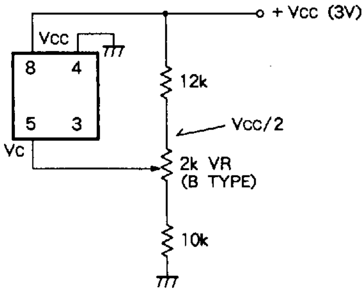
(2) PROGRAMMABLE ATTENUATION CIRCUIT



ATTENUATION VS. AMBIENT TEMPERATURE (TEMPERATURE COMPENSATION)



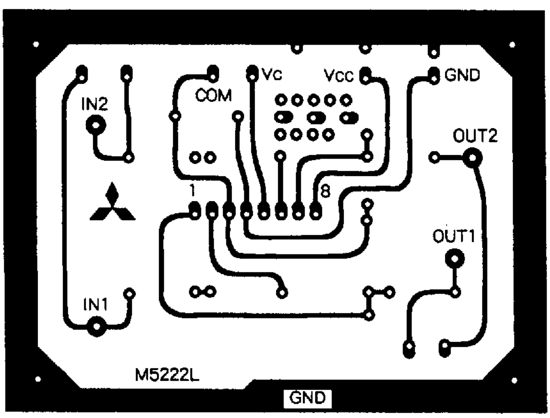
(3) CONTROL APPLICATION WITH EXISTING VOLTAGE CONTROL



Units Resistance : Ω
Capacitance : F

PRINTED CIRCUIT BOARD FOR CIRCUIT TESTING

PRINTED CIRCUIT BOARD WIRING DIAGRAM (COPPER FOIL SIDE)



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