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High Performance and Versatile Bi-CMOS Electronic Volume IC

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SUMMARY The high performance and versatile electronic volume IC has been realized by the 15V high voltage Bi-CMOS process. Mixed use of bipolar and MOS devices has introduced new functions such as buffer amplifiers, a low level oscillator, a temperature compensated D/A converter and a reference voltage generator.

1. Introduction

Electronic volume ICs using CMOS circuit and process technology have several advantages in easiness to use, low power and battery back-up possibility. On the other hand, they have several disadvantages in frequency characteristic at low signal output level, noise injection from oscillator part to analog parts, necessity of external buffer amplifiers[1], insufficient lineality at DC monitor output and lack of driving capability of the reference voltage generator.

This letter describes that there exists the solution not to have those disadvantages when mixed bipolar and CMOS technology is used for IC realization, and about the excellent IC performance obtained as a result of actual IC fabrication by using 15V high voltage Bi-CMOS process.

2. System Structure

Figure 1 shows the block diagram of the electronic volume IC that has been newly developed. Two volumes are prepared for the purpose of 2 channel use. Each consists of 10dB and 2dB step ladder resistors, and a buffer amplifier. The adjustment of the attenuation level is performed by switching analog switches connecting to ladder resistors, which is controlled by 10dB and 2dB up/down counters. At the same time, the content of the 10dB up/down counter is monitored and put out to the DC-OUT terminal by converting digital data to analog DC level. The control of the up/down counters is performed by the external keys and oscillator output is led to the counters. Reference voltage generator and battery back-up function are also included.

3. Bi-CMOS Circuits

Mixed use of bipolar and CMOS devices can enhance the performance of each function. Bipolar and/or Bi-CMOS circuits are used in an oscillator, buffer amplifiers, a DC-OUT block, a reference voltage generator and a bandgap voltage reference.

The oscillator basically consists of bipolar devices in order to suppress the oscillation voltage swing to avoid the noise injection problem as shown in Fig. 2. The oscillation level is only 1 V_{p-p} and this is converted to the CMOS level voltage swing by the mixed bipolar and CMOS circuit. MOS devices are also used to make the oscillation stop by clamping appropriate terminals to

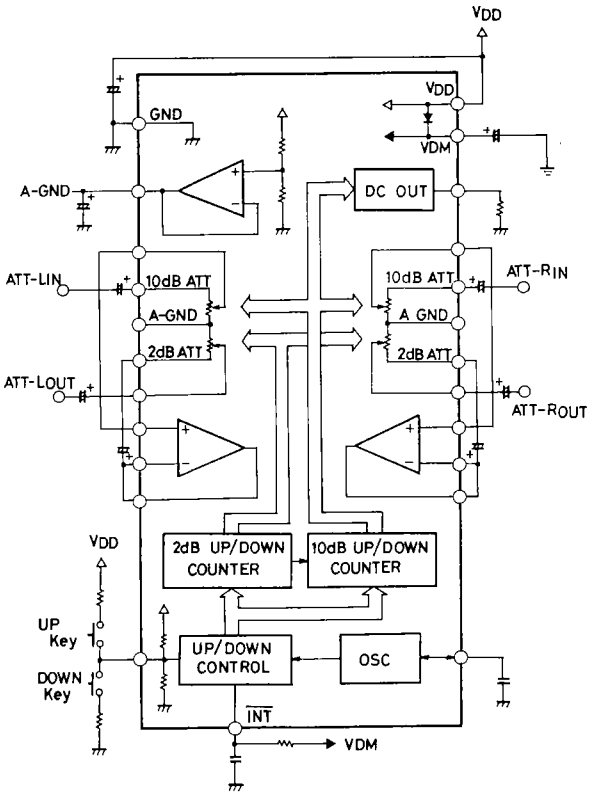

Fig. 1 Block diagram of the Bi-CMOS volume IC.

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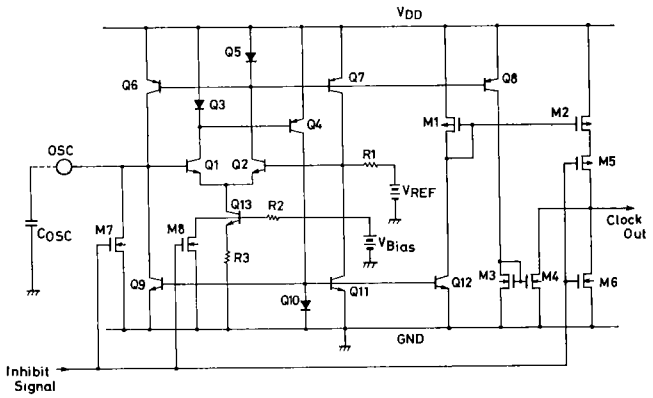

Fig. 2 Bi-CMOS low level oscillator circuit.

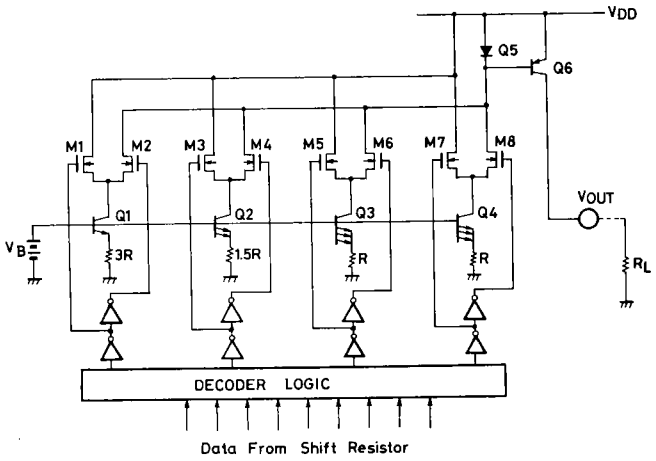

Fig. 3 Bi-CMOS D/A converter circuit.

the ground when the inhibit signal is applied. DC-OUT is a digital to analog converter that monitors the content of the 10dB step up/down counter. Conventional MOS D/A converter uses the MOS devices for current sources, however, this usually shows the large temperature dependance and poor matching of the current sources. The problem can be avoided by using bipolar transistors and resistors in current sources as shown in Fig. 3. MOS devices are used for current switches because they don't get into saturation as bipolar devices do when the switching control signal has CMOS level swing. In Fig. 3, V_B is generated by the bipolar bandgap voltage reference circuit and the temperature dependance can be compensated.

Reference voltage generator is very useful when the system is used by the single power supply and it offers the analog ground point to ladder resistors. To ensure the performance, low output impedance is necessary. This has been done by using the bipolar amplifier. Low noise and high performance characteristics are also required for buffer amplifiers. Bipolar amplifiers are also used for this purpose and typical equivalent input noise is only $3\mu V_{rms}$.

Table 1 Bi-COMS volume IC performance.

ITEM	CHARACTERISTICS	UNIT
Supply Voltage	6.0 ~ 12.0	V
Supply Current	5.0	mA
Back-up Current	0.5	μA
DAC Resolution	4	bit
Attenuater	10 / 2	dB/STEP
T · H · D	0.005	%
OSC Level (up down)	1.0	Vp-p
Op. Amp. Voltage Gain	80	dB
Slewrate	0.8	V/μsec
Band Width	3.0	MHz
Chip Size	3.7 x 4.8	mm²
Package	MFP 24 pin	
Process	Al Gate - Bi CMOS	
Elements Count	300 ele + 700 gate	

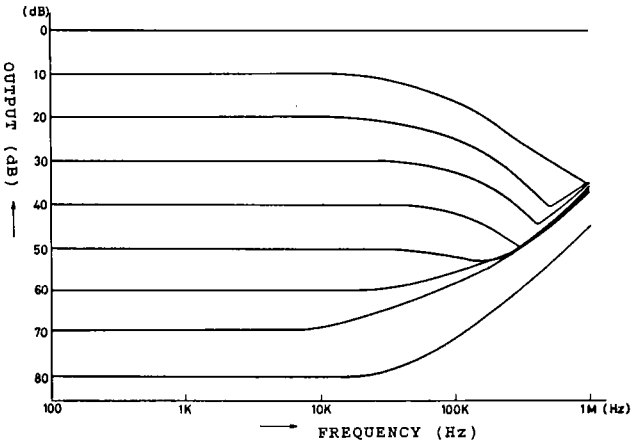

Fig. 4 Output level frequency characteristic.

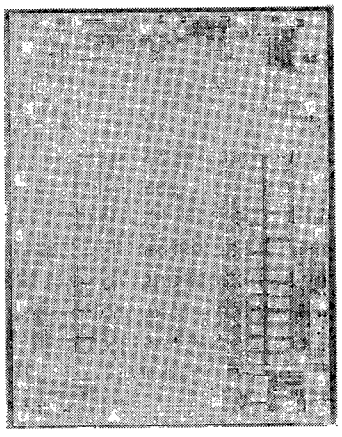

Fig. 5 Die photograph of the Bi-CMOS volume IC.

4. IC Characteristics

The electronic volume IC with blocks shown in Fig. 1 has been realized by using 6 μm aluminum gate 15V high voltage Bi-CMOS process. Overall IC performance is summarized in Table 1. The graph shown in Fig. 4 is

the frequency vs. output signal level characteristic of the volume. The oscillation level is only $1\,V_{p-p}$. The distortion at 0 dB output at 1 kHz is 0.005 %. The improvement of the low output level frequency characteristic can be seen in Fig. 4. This is because the mixed R-$2R$ type and series type resistors are used for the ladder network[1]. Total current consumption is only 5 mA. Battery back-up capability is also offered. Back-up current is only 0.5 μA. The chip size of the IC is $3.7\times4.8\,mm^2$ and die photograph is shown in Fig. 5.

5. Conclusion

The enhancement in the characteristics of the mixed analog and digital function has been verified by the use of Bi-CMOS circuit and process technology applied to electronic volume IC.

Acknowledgement

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Reference

(1) M. Sato, K. Suzuki and K. Akutsu: "A volume and tone control IC for Hi-Fi audio", IEEE J. Solid-State Circuits, **SC-16**, 6, pp. 682-688 (Dec. 1981).